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PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL
AND PHYSICAL SCIENCES OF THE PACIFIC REGION

IN THIS ISSUE: Tester and Trefz — *Food of the Abolehole* • Jameson and Toshioka — *Chiggers from Southern Korea* • Gosline, Brock, Moore, Yamaguchi — *Fishes Killed by Volcanic Eruption. Part I* • Matthews — *Spermatophoric Mass of* Parribacus antarcticus • Merrill — *Notes on "De plantis esculentis"* • Woodward — *Genus* Felisacus *Distant* • Hand — *Pacific Species of "Lar"* • Gosline — *Fishes Killed by Volcanic Eruption. Part II* • Kuroda — *Birds of Marcus Island* • Brock — *Biology of the Aku* • NOTES

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(Continued on inside back cover)

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The Food of the Aholehole, *Kuhlia sandvicensis* (Steindachner), in Hawaiian Waters[1]

ALBERT L. TESTER and SHIRLEY M. TREFZ[2]

THE AHOLEHOLE, also known as the mountain bass, is an inshore fish which occurs in salt, brackish, and fresh waters throughout the Hawaiian Island chain. The young are fairly abundant along rocky shores, in tide pools, and within the mouths of streams which are connected to the sea. Juveniles are frequently encountered under wharves, in larger tide pools, and in brackish or fresh-water ponds, and streams. Adults are found in the caverns of wave-swept coral reefs, in the pounding surf at the base of cliffs, in sunken barges and other underwater obstructions, and, occasionally, as schools in more open water.

A study of the food of the aholehole was undertaken in connection with a general investigation of the life history of the species to ascertain whether or not it could be reared in ponds. The investigation has been financed by and conducted under contract with the Industrial Research Advisory Council of the Territory of Hawaii (Project No. 29).

We are indebted to Dr. Leonard D. Tuthill and Dr. D. Elmo Hardy of the University of Hawaii and Dr. Willis W. Wirth of the U. S. National Museum for the identification of certain insects; to Dr. Maxwell S. Doty and Dr. Albert H. Banner of the University of Hawaii for the identification of algae and certain invertebrates.

[1] Contribution No. 40, Hawaii Marine Laboratory.

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MATERIALS AND METHODS

Twenty-two samples of aholehole, comprising 202 fish with food in their stomachs, were examined (Table 1). Small fish from fresh-water streams (samples 1 to 5), from a brackish-water canal (sample 6), and from tide pools or rocky shores (samples 7 to 14) were caught by seine, dip net, or, in a few cases, hook and line. Medium-size fish (samples 15 and 16) were caught from rocky shores by hook and line. Large fish were caught by poisoning coral reef areas (samples 17 to 20), by spear fishing at a sunken barge (sample 21), and by trap in an inshore channel (sample 22).

For the most part the small and medium-size fish were preserved in formalin immediately after capture. Later the fish were measured, the stomach removed, and the contents examined under a dissecting microscope. The length range of each sample is included in Table 1. Length is defined as the distance from the tip of the closed jaws to the end of the vertebral column (located with a probe). The large fish were measured and dissected as soon as possible after capture. In some cases, the unopened stomachs were placed in vials of formalin; in others the stomachs were opened and the contents were preserved in the vials. The latter procedure seemed more satisfactory, as digestion was halted sooner and the contents were more readily identified because of their better state of preservation.

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TABLE 1

AHOLEHOLE SAMPLING DATA, WITH PERCENTAGE BY BULK OF VARIOUS FOOD ITEMS FOUND IN THE STOMACHS

GROUPS, SAMPLE NUMBER, AND LOCALITY	DATE	NUMBER	SIZE (RANGE IN MM.)	ALGAE (AND OTHER PLANTS)	FORAMINIFERA	ANNELIDS	CRUSTACEA	INSECTS	SPIDERS	MOLLUSCS	OTHER
Small Fish from Fresh Water — 1 Bellows Field Stream	1/ 6/52	10	20–23	43.0	21.0	...	19.5	4.0	...	...	12.5
2 Bellows Field Stream	1/ 6/52	10	45–64	73.9	...	...	0.1	16.0	...	...	10.0
3 Bellows Field Stream	1/26/52	6	54–65	85.0	...	...	1.7	13.3	...	...	...
4 Kaaawa Stream	2/15/52	10	23–27	68.3	...	...	...	29.7	2.0	...	...
5 Kaaawa Stream	9/10/52	10	22–39	58.0	...	...	7.5	34.5	...	...	...
			Mean	65.6	4.2	...	5.8	19.5	0.4	...	4.5
Small Fish from Salt Water — 6 Ala Wai Canal	3/ 4/52	5	28–35	...	...	...	33.0	4.0	...	63.0	...
7 Diamond Head	1/22/52	8	22–35	6.2	10.2	...	80.8	0.8	...	0.2	1.8
8 Diamond Head	4/15/52	10	32–50	+	7.8	...	27.0	46.9	...	18.3	...
9 Kuhio Beach	6/11/52	10	25–37	15.8	...	...	74.5	9.7	...	...	...
10 Sandy Beach	1/26/52	8	30–36	...	1.4	...	40.9	56.3	1.3	0.1	...
11 Kawailoa	2/ 8/52	10	23–30	9.5	...	4.0	53.0	26.0	5.5	2.0	...
12 Kualoa	5/15/52	10	23–45	...	47.9	...	29.6	22.2	0.1	0.2	...
13 Lahilahi Point	2/13/52	10	21–37	13.0	0.5	...	70.5	15.5	...	0.5	...
14 Waimea	2/ 8/52	10	19–40	+	+	0.4	23.4	74.7	1.5	...	...
			Mean	4.9	7.5	0.5	48.1	28.5	0.9	9.4	0.2
Medium and Large Fish from Salt Water — 15 Kaena Point	2/12/52	10	59–105	6.0	...	0.5	63.3	17.5	1.0	...	11.7
16 Makapuu Point	12/23/51	10	73–138	...	...	...	94.0	6.0	...	...	...
17 Hauula	5/11/52	13	153–201	7.3	...	64.2	26.1	+	...	...	2.2
18 Hauula	7/ 8/52	14	164–204	0.9	...	+	97.3	0.3	...	0.1	1.5
19 Hauula	10/ 4/52	5	157–191	...	...	...	98.0	2.0	...	...	...
20 Diamond Head	6/23/52	8	159–193	0.6	...	0.6	98.7	...	...	...	...
21 Off Fort DeRussy	3/22/52	5	142–190	...	...	...	90.6	...	+	...	9.4
22 Pearl Harbor Entrance	2/19/52	10	132–172	...	...	40.7	53.1	0.2	...	+	6.0
			Mean	1.9	...	13.3	77.6	3.3	0.1	+	3.8

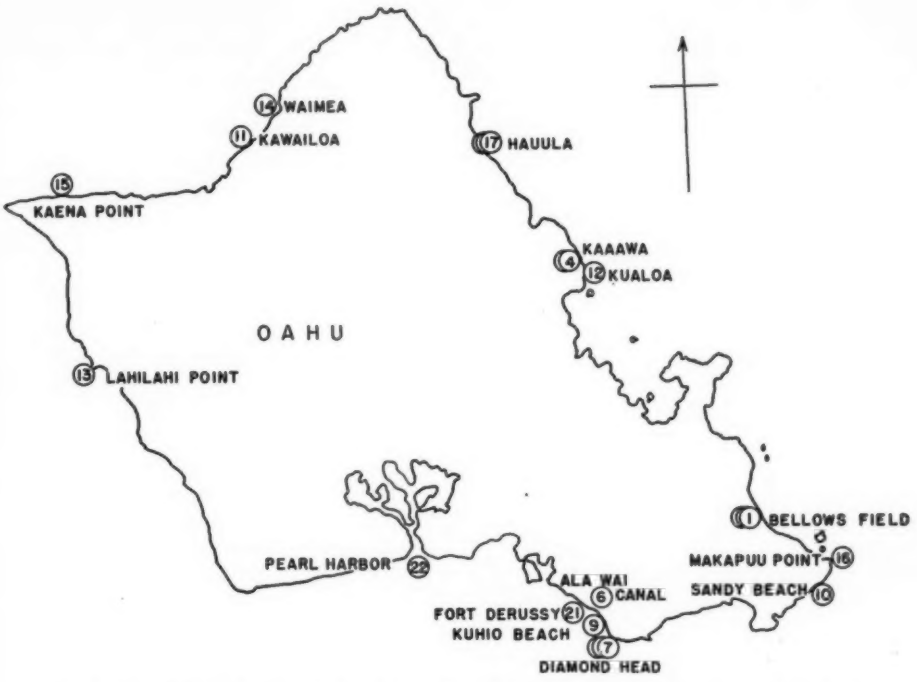

FIG. 1. Map of Oahu showing the location of places from which aholehole samples were obtained.

The items in the stomachs were identified, counted when not too numerous, and expressed as a percentage (estimated) by bulk of the total. In large fish the volume of the contents was also determined, but as this did not vary greatly (*ca.* 2 to 6 ml.) it was not incorporated into the calculations. For each sample a table was prepared showing the frequency of occurrence and the average percentage by bulk of each item. Only the latter figures are included in Table 1.

Organisms were identified usually to order or suborder, often to family, and more rarely to genus and species.

The places of collection, all on Oahu, may be located on the accompanying map (Fig. 1).

RESULTS

It may be seen from Table 1 that aholehole eat seven major types of food: algae, foraminifera, annelids, crustacea, insects, spiders, and molluscs. It is apparent from the grand means that the relative importance of the major groups differs with size-group of fish and with habitat. The results will be discussed according to these two categories.

Small (20–65 mm.) Fish from Fresh Water

Small aholehole from both Bellows Field (samples 1 to 3) and Kaaawa Stream (samples 4 and 5) contained algae, insects, crustaceans, and foraminifera, in order of decreasing percentage. The samples were taken from within the stream mouths in water which was practically fresh (chlorinity 1 to 3 p.p.m.).

Algae and other plant material (averaging 65.6 per cent of the food) occurred in 41 of the 46 stomachs examined. Filamentous red algae (*Compsopogon*) was the most abundant form in samples from both localities. Fila-

mentous green and blue-green algae were also common. Diatoms of various species (*Bacillaria*, etc.) and other one-celled forms such as *Oocystis* were numerically abundant in some stomachs but in bulk constituted a minor item. A few stomachs contained decomposed material, mostly from higher plants, which occurs as a light carpet over the sandy bottom of the stream.

Insects (19.5 per cent) occurred in 19 of the 46 stomachs. They consisted entirely of terrestrial forms—mostly small ants, but also small beetles, springtails, leaf hoppers, and bugs, in order of decreasing percentage. The small ants, of common occurrence in the stomachs, must have fallen into the water by accident. The springtails were probably taken from the surface, where they hop about. Probably the other insects were taken when they accidentally landed on the surface or when they were flying close to it.

The crustaceans (5.8 per cent), occurring in 10 of the 46 stomachs, consisted primarily of fresh-water shrimp larvae, copepods, and amphipods. Foraminifera of several species (4.2 per cent) occurred in four out of six stomachs in one sample only. Similarly small spiders (0.4 per cent) occurred in two out of ten stomachs in one sample. Other food items (4.5 per cent) included unidentified eggs and the remains of a small tadpole (?), each of which occurred in one stomach only.

Small (19–50 mm.) Fish from Salt Water

The small aholehole from Ala Wai Canal (sample 6) have been grouped with those from salt water (samples 7 to 14) as the stomachs contained similar food items, although the chlorinity (13.7 p.p.m.) showed somewhat brackish conditions as compared with those along the seashore (18–19 p.p.m.).

There is considerable variation in the predominating food organism in the various samples. Molluscs were dominant in the sample from Ala Wai Canal; crustacea were dominant in one sample from Diamond Head (No. 7) and in those from Kuhio Beach, Kawailoa, and Lahilahi Point; insects were dominant in the other Diamond Head sample (No. 8) and in those from Sandy Beach and Waimea; foraminifera were dominant in the sample from Kualoa. There seems to be no general relationship between the type of dominating organism and the particular habitat (sandy shore, rocky shore, tide pool). In general, however, crustacea and insects are much more abundant and algae much less abundant in the stomachs of small fish from salt water as compared with those from the fresh-water streams. The difference is interesting but not surprising—it probably reflects a difference in the relative availability of the three types of food rather than a difference in feeding habit.

The food organisms found in the stomachs of small aholehole from salt (and brackish) water may be ranked in the following order of decreasing average abundance: crustacea, insects, molluscs, foraminifera, algae, spiders, and annelids.

Crustacea (48.1 per cent) of one kind or another occurred in 76 of the 81 stomachs. Table 2 shows the various groups arranged according to the average percentage by bulk and shows the number of stomachs in which they occurred.

The copepods, including suborders Cyclopoida, Harpacticoida, and Calanoida, were the most important item of the crustacean diet. They were followed by small amphipods (mostly Gammaridea) and isopods (including Tanaioida). Other crustacean forms occurred infrequently and formed but a small propo-r tion of the food.

Insects (28.5 per cent) occurred in 54 of the 81 stomachs. They occurred in the following decreasing order of abundance: midges, ants, wasps, roaches, beetles, bugs, thrips, and leaf hoppers. Midges and ants, together, comprised the bulk of the insects.

The midges, identified as *Clunio littoralis* by Wirth, occurred in the stomachs as larvae and pupae, but mostly as adults. They were found in all samples taken from tide pools and rocky shores but not in the sample from Ala

TABLE 2
CRUSTACEAN FOOD IN THE STOMACHS OF SMALL AHOLEHOLE FROM SALT WATER, SHOWING FREQUENCY OF OCCURRENCE AND PERCENTAGE BY BULK

CRUSTACEA	NUMBER OF OCCURRENCES	PER CENT OF TOTAL FOOD
Copepods	70	22.3
Amphipods	27	10.0
Isopods	18	4.0
Crab zoea and megalops	15	2.6
Shrimp zoea	3	0.3
Ostracods	11	0.2
Mysids	3	0.1
Barnacle nauplii	1	0.1
Unidentified remains	19	8.5

Wai Canal (with rock walls) nor in that from Kuhio Beach (a sandy shore). They were particularly abundant in the sample from Waimea, occurring in nine of the ten stomachs and comprising 61.0 per cent of the total contents. In a letter to Dr. Hardy, Dr. Wirth states: "Since approximately a fourth of the hundred or so specimens were females, I would not be surprised if the fish were feeding on the midges in the beds of algae where they breed. Since the females are wingless they can only crawl around the breeding places, although some are transported by the males during copulation." This insect, one of the few that breeds in salt water, thus forms an important item in the diet of the small aholehole.

Ants, mostly small adults, occurred often in small aholehole from tide pools and rocky shores. They were particularly abundant in one sample from Diamond Head (No. 8) where they occurred in seven of the ten stomachs and formed 31.5 per cent of the total contents. The ants, which are very common along all shores, doubtless were blown or fell into the water where they were eaten. Some of the winged forms, such as wasps, beetles, etc., may have been taken when they were flying low over the surface or when they accidentally landed on the surface. Although most of the whole insects found in the stomachs were of very small size, a few large legs and wings from unidentified species indicated that the aholehole would also tackle larger forms, nibbling at them until they were consumed.

Molluscs (9.4 per cent) occurred in 22 of the 81 stomachs. They consisted of pelecypod and gastropod veligers and postveligers. There was an unusual abundance of pelecypod veligers in the sample from Ala Wai Canal in which they occurred in all five specimens and formed 63 per cent of the total contents.

Foraminifera (7.5 per cent) occurred in 29 of the 81 stomachs. They were particularly abundant in the Kualoa sample, occurring in nine of the ten stomachs and forming 49.9 per cent of the contents for this one locality.

Algae (4.9 per cent) occurred in 25 of the 81 stomachs. They consisted of the red and green thallus and branched forms common to tide pools and also included diatoms and other one-celled species (of minor importance). The low percentage of algae is in marked contrast to the high percentage which occurred in the stomachs of small aholehole from fresh-water streams.

Annelids (polychaete worms) occurred in only three stomachs. Other items included fish eggs found in two stomachs.

Medium (59–138 mm.) and Large (132–204 mm.) Fish from Salt Water

Medium-size fish (samples 15 and 16) and large-size fish (samples 17 to 22) are grouped as the food was similar and both came from similar habitats—localities exposed to the surf of the open sea where the water is of high chlorinity (19 p.p.m.).

It will be noted from Table 1 that there is less variation in the type of dominant food organism in the samples of this group than in those of the small fish from salt water. Crustacea were most abundant in seven and annelids in one of the eight samples. Compared with the food of the small salt-water fish, there was a marked increase in the per-

centage of crustacea and annelids and a marked decrease in the percentages of all other types of food. No foraminifera were found. The organisms occurred in the following order of decreasing abundance: crustacea, annelids, insects, algae, spiders, and molluscs, with the last two forming very minor items.

Crustacea (77.6 per cent) were by far the most important food of the medium and large aholehole, occurring in every one of the 75 stomachs. The various kinds were distributed as indicated in Table 3.

TABLE 3
CRUSTACEAN FOOD IN THE STOMACHS OF MEDIUM AND LARGE AHOLEHOLE FROM SALT WATER, SHOWING FREQUENCY OF OCCURRENCE AND PERCENTAGE BY BULK

CRUSTACEA	NUMBER OF OCCURRENCES	PER CENT OF TOTAL FOOD
Crab megalops, zoea, and adults	63	49.6
Stomatopod larvae	20	6.9
Amphipods	36	6.3
Shrimp adults and larvae	24	1.8
Copepods	15	1.2
Mysids	10	1.1
Isopods	8	0.8
Euphausids	6	0.1
Ostracods	5	+
Nebaliacians	1	+
Unidentified remains	15	9.8

Crab (Brachyura) megalops were the most important item of the crustacean diet; zoea were common but of minor bulk; small adults were found in only two stomachs. Anomura larvae were found in one sample (No. 21). The remainder of the crustacean food consisted mostly of stomatopods (alima larvae) and amphipods (mostly gammarids, but also hyperiids and caprellids). In contrast to the crustacean diet of the small salt-water fish, copepods were of relatively minor importance to the medium and large salt-water fish. The larger fish tended to eat larger organisms.

Annelids (13.3 per cent) were found in 22 of the 75 stomachs and consisted of unidentified motile polychaete worms. They were mostly of small size (*ca.* 2 cm.), but fragments of larger worms occurred occasionally.

Insects (3.3 per cent) were found in 20 of the 75 stomachs. They were more common in the stomachs of medium-size fish caught at the bases of cliffs than in those of the large-size fish from the outer edges of the reef and the more open water. In the former, the insects consisted of midges (*Clunio*), beetles (Carabidae and Scarabaeidae), and a wasp. In the latter, they consisted of salt-water striders (*Halobates*), a beetle (Staphylinidae), and an ant.

Algae (1.9 per cent) were relatively scarce. Two spiders (0.1 per cent) were found. Molluscs (+ per cent) included a small snail and postveligers. Other items (3.8 per cent) included chaetognaths, sponge gemmules, bottom debris (containing both plant and animal remains), eggs, and fish larvae.

Variation in the Proportion of Stomachs Containing Food

The stomachs of seine and dip-netted small aholehole (19 to 30 mm.) taken from both fresh and salt water almost invariably contained food in either the stomach or gut, although in some cases it was present in traces and was considerably digested. This agrees with the general rule pointed out by Ricker (1946) and substantiated by Orcutt (1950) that, on capture, small fish more frequently contain food in their stomachs than do large fish, a fact which is probably related to their greater activity and faster growth rate. The stomachs of small fish (30 to 50 mm.) taken by hook and line were frequently empty or contained only the bait which was used. Doubtless this method of fishing selected the hungrier individuals.

In the large fish taken by trap (sample 22) the stomachs of all 16 fish contained food. In those taken by spear fishing (sample 21 and others not reported), 12 out of 34, or 35 per cent, contained food. In those taken by poisoning (samples 17 to 20), 100 out of 226, or 44 per cent, contained food. In all these

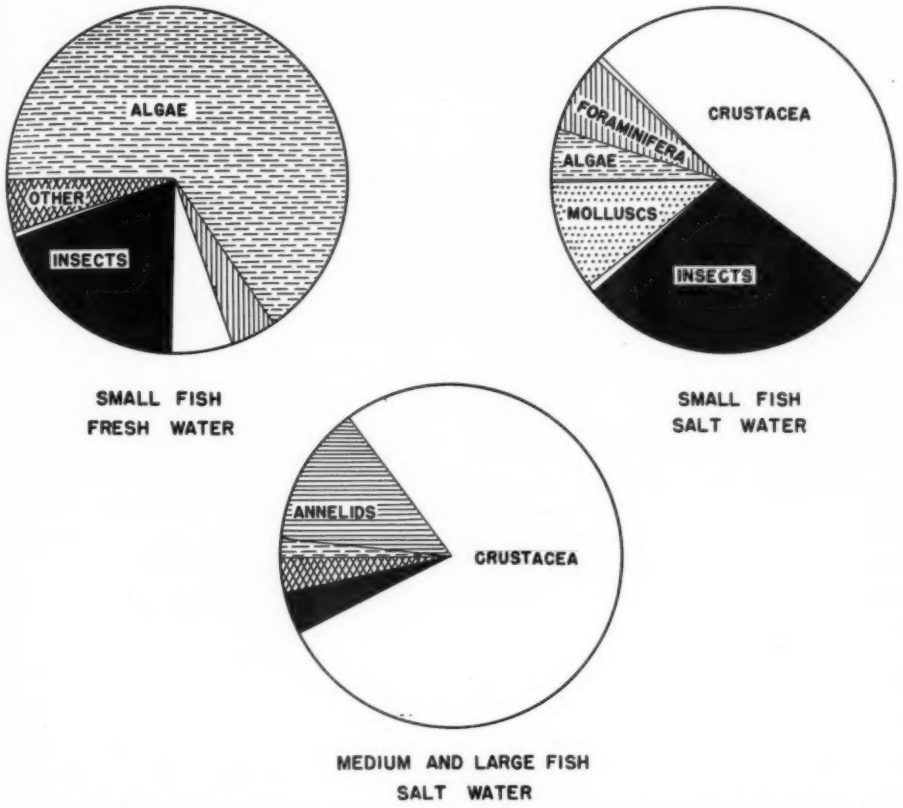

FIG. 2. Diagrams illustrating the food of small aholehole from fresh water, small aholehole from salt water, and medium and large aholehole from salt water.

fish, the gonads were either spent or in early stages of development of the eggs and sperm. In two samples taken by poisoning from Diamond Head (Dec. 22, 1951, and Dec. 23, 1952), the stomachs of all 199 fish were empty except for one which contained sand and gravel. In these fish the gonads were almost fully ripe; in some cases eggs and milt would "run" with pressure on the sides of the fish. This indicates that the aholehole, like several other species, ceases to feed when ready to spawn.

SUMMARY AND DISCUSSION

As illustrated in Table 1 and Figure 2, there are certain differences in the food of small aholehole in fresh water, small aholehole in salt water, and medium and large aholehole in salt water. The small fish living in streams eat mostly algae and insects. The small fish living in tide pools and along rocky shores eat mostly crustacea and insects. The medium and large fish living along surf-pounded cliffs, in the caverns of the outer reef, and in other exposed localities eat mostly crustacea and annelids. Whereas the crustacean diet of the small salt-water fish consists mostly of small copepods and amphipods, that of the medium and large fish consists mostly of the larger crab and stomatopod larvae. These differences, although striking, are not unexpected. They are doubtless related to differences in the

dominant types of food available in the three habitats and to an increasing ability of the fish to take larger organisms as it grows larger and the gape of its mouth increases.

The large percentage of insects found in the stomachs of small fish was unexpected. In the fresh-water samples these were mostly terrestrial forms (ants, beetles, etc.) which had fallen into the water or accidentally landed on the surface. In the salt-water samples they included terrestrial forms (ants, wasps, etc.) but consisted largely of midge (*Clunio*) adults and larvae which breed in salt water along the rocky shores. Insects occurred only rarely in the stomachs of large fish and included midges (*Clunio*) in those taken from the base of cliffs and salt-water striders (*Halobates*) in those taken farther from shore, as well as a few terrestrial species.

The aholehole might be described as omnivorous but with a preference for motile animal forms. Although algae of various species were abundant in the salt-water habitat, they were eaten to only a small extent. The fact that they formed such a large percentage of the food of the small fish in fresh water was probably because motile animal life, of a size suitable to the small fish, was relatively scarce.

Superficially the aholehole resembles the fresh-water Centrarchidae in both appearance and feeding habits. However, in both the smallmouth black bass (Tester, 1932) and the largemouth black bass (Murphy, 1949) there is a change in diet with increase in size to include fish as an important food item. This does not occur in the aholehole, even though larval and juvenile fish of suitable size are present in the habitat. Larval fish were found in only four stomachs and formed a very minor item in the diet of the larger aholehole.

From a study of the natural food, one would infer that crustacea would serve as an ideal bait in angling for the medium and large fish. This is true; we have found shrimp to be the best bait, although the fish will also respond to a hook baited with pellets of bread. Both vegetable material such as bread and poi and animal material such as ground fish and shrimp may be used to chum aholehole to the surface.

As is true of several other species, the aholehole appears to cease feeding when ready to spawn.

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Notes on Some Chiggers (Acarina: Trombiculidae) from Southern Korea[1]

E. W. JAMESON, JR., and SEIICHI TOSHIOKA[2]

THE FOLLOWING ACCOUNT is based upon specimens collected by members of the 207th Preventive Medicine Survey Detachment and the 37th Preventive Medicine Survey Detachment in southern Korea. It is undoubtedly incomplete, and the sampling may be selective: the hosts examined came mostly from agricultural areas and near dwellings. Despite the inevitable shortcomings of such a preliminary survey, this account will serve as a beginning for a study of the trombiculid fauna of Korea.

The area covered by this paper is slightly beyond that discussed by Womersley (1952) in his voluminous work on chiggers of the Asiatic-Pacific area; and this account is, in a small measure, a supplement to the much larger one by Womersley. Six species of chiggers were described from regions to the north of Korea by Schluger (1948), and two of those species have been collected in southern Korea. Pertinent to this account is the apparently heretofore largely overlooked paper by Kanda, mentioning two species of chiggers from Korea.

There are reported here several species previously known only from Japan, two species described by Schluger from more northerly regions of the Asiatic mainland, and one species known also from North America. Two species are described as new in this paper. There is in preparation an illustrated account of Japanese chiggers, and the Japanese species known from southern Korea are not reillustrated in this paper.

The illustrations in this paper were made in Kyoto, Japan, and are the work of Mr. M. Endo, Mr. S. Shibata, Mr. A. Shimazoe, and Mr. K. Daishoji. These artists were under the direct supervision of Mr. K. Yamazaki. The bulk of the material collected was mounted by Miss Y. Yoshida.

We would like to express our appreciation to Major Paul W. Oman, MSC, under whose direction and encouragement this work was done; to Dr. James M. Brennan for professional council in this study; to Professor Harujiro Kobayashi for calling our attention to and loaning us a copy of the paper by Kanda; and to Lt. Col. Robert Traub, MSC, for a photostatic copy and translation of the paper by Schluger.

Key to the Chiggers of Southern Korea

1. Anteromedian scutal seta absent . . . . . *Gahrliepia brennani* var. *ventralis*
   Anteromedian scutal seta present (single or double) 2

[1] Studies upon which this paper is in part based were conducted under Contract No. DA-49-007-MD-242, between the Regents of the University of California and the Department of the Army. The work was initiated while the senior author was associated with the 406th Medical General Laboratory and the Far East Medical Research Unit in Japan during the period January–October, 1952. Logistical support for the preparation of the specimens and illustrations was supplied by the U. S. Army Hospital, 8164th Army Unit, by special arrangement with the above-mentioned organizations.

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2. Anteromedian scutal setae paired; coxa I with two setae; all legs with six segments ..... *Shunsennia tarsalis*
   Anteromedian scutal seta single; coxa I with one seta; all legs with seven segments 3
3. Sensillae capitate; palpal claw five-pronged ..... genus *Euschöngastia*, 4
   Sensillae flagelliform; palpal claw three-pronged ..... genus *Trombicula*, 5
4. Two pairs of humeral setae .. *E. ikaoensis*
   One pair of humeral setae ... *E. koreaensis*
5. Scutum more or less pentagonal; one or more mastitarsalae III ..... subgenus *Neotrombicula*, 12
   Scutum more or less rectangular; with no mastitarsalae III ..... subgenus *Leptotrombidium*, 6
6. Ventral tibial seta of palpus feathered ... 7
   Ventral tibial seta of palpus nude 8
7. Base of sensillae nude or with very minute, closely appressed barbs; first posthumeral row of setae usually ten .*palpalis*
   Base of sensillae with small but conspicuous, divergent basal barbs; first posthumeral row of setae usually eight ..... *orientalis*
8. With one nude seta on telofemur III; dorsal palpal tibial seta nude; spur on tarsus II longer than spur on tarsus I .. .. *subakamushi*
   With no nude seta on telofemur III; dorsal palpal tibial seta feathered; spur on tarsus II shorter than spur on tarsus I 9
9. Scutum more than twice as wide as long ..... *hiranumai*
   Scutum less than twice as wide as long 10
10. Sensillae with conspicuous, divergent basal barbs ..... *pallida*
    Sensillae basally nude or virtually so .. 11
11. Scutum with a pair of crescent-shaped marks near the anterior margin; barbs on dorsal setae short ..... *myotis*
    Scutum without crescent-shaped marks; dorsal setae rather short, but with numerous long barbs ..... *subintermedia*
12. With three mastitarsalae III ..... *tamiyai*
    With one or two mastitarsalae III 12
13. With two mastitarsalae III .... "sp." of Kanda
    With one mastitarsala III 13
14. With two pairs of humeral setae .. *japonica*
    With one pair of humeral setae ... *nagayoi*

Shunsennia tarsalis
Jameson and Toshioka, 1953

Shunsennia tarsalis Jameson and Toshioka, 1953. Biol. Soc. Washington, Proc. 66: 89–92.

DIAGNOSIS: Palpal femoral, genual, and dorsal and ventral tibial setae densely feathered; lateral tibial seta long with 3–4 small barbs. Palpal claw three-pronged. Galeal seta with a few barbs. Coxal setae 2–1–1. Sternal setae 0–4. Sensellae nude. Scutal measurements of holotype: AW-83, PW-106, SB-35, ASB-61, PSB-20, AP-20, AM-84, AL-76, PL-126, S-109.

DISTRIBUTION AND HOSTS: Known only from the original data.

TYPE DATA: Holotype from (?)*Clethrionomys rufocanus;* 15 miles northwest of Wonju; March 13, 1952. One paratype with same data and one paratype from *Apodemus agrarius*, 10 miles west of Chunchon; February 16, 1952. Holotype deposited at the U. S. National Museum.

Gahrliepia (Walchia) brennani var. ventralis Womersley, 1952
Fig. 1

Gahrliepia (*Walchia*) *brennani* var. *ventralis* Womersley, 1952. So. Austral. Mus. Rec. 10 (pt. 1): 295.

DIAGNOSIS: Palpal femoral seta nude or branched; other palpal setae nude. Palpal claw three-pronged (stated to be two-pronged in original description). Galeal seta nude. Scu-

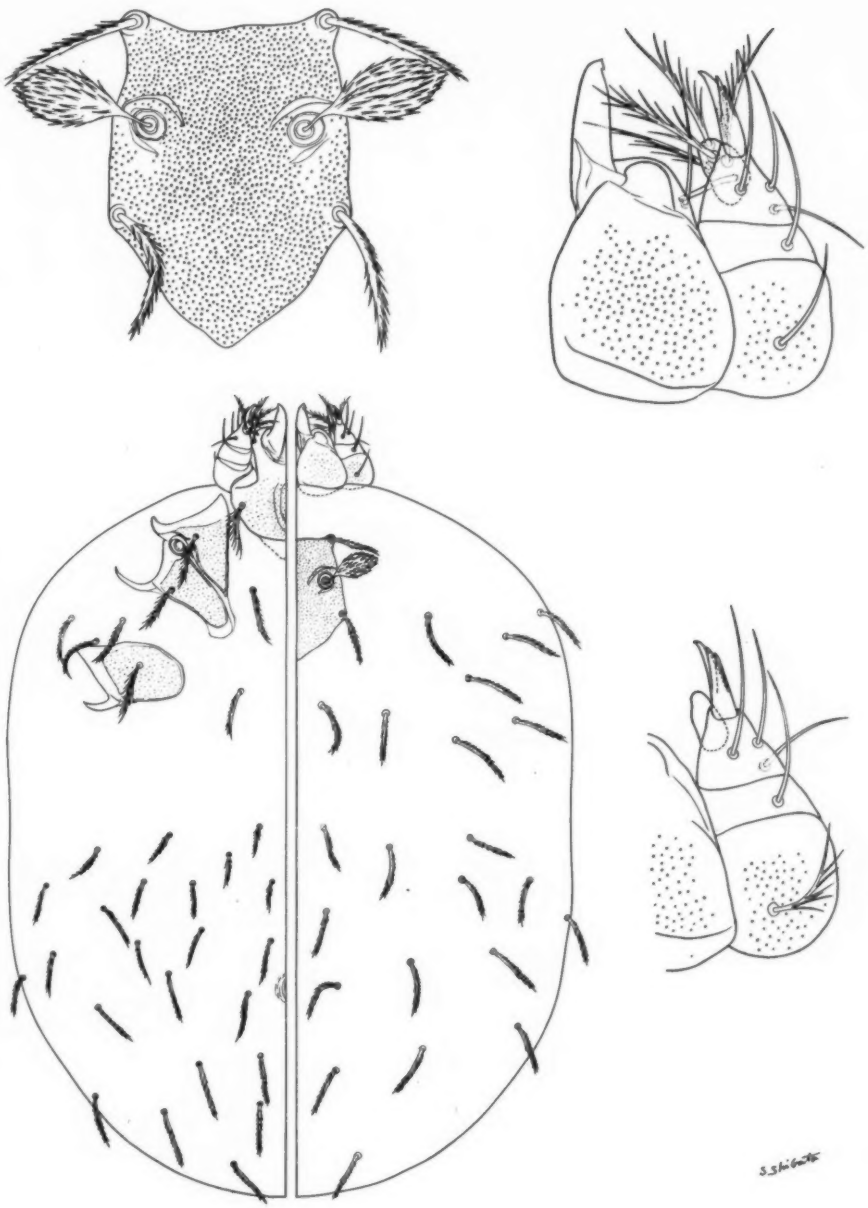

Fig. 1 *Gahrliepia brennani* var. *ventralis* Womersley

tum five-sided, the posterior sides more or less straight and forming a right angle with each other. Coxal setae 1–1–1. Sternal setae 2–2. Several setae between coxae II and III. Humeral setae variable, three to five pairs. Scutal measurements of a mean of 17 specimens (given by the describer): "AW-37.5, PW-54.1, SB-32.8, ASB-21.8, PSB-57.8, AP-37.6, AL-27.3, PL-26.8, S-33.5." Scutal measurements of a south Korean specimen: AW-44, PW-50, SB-35, ASB-26, PSB-49, AP-45, AL-37, PL-35, S-34.

DISTRIBUTION AND HOSTS: Originally known only from Ulu Langat Forest Reserve, Selangor, from *Rattus bowersi*. Known in southern Korea from an area 9 miles southeast of Chorwon, Seoul, and in Chipori from *Microtus* sp. and *Apodemus agrarius*.

TYPE DATA: From *Rattus bowersi*, Ulu Langat Forest Reserve, Selangor, Federated Malay States; June 13, 1950.

COMMENT: The designation of *ventralis* as a variety is unfortunate, as it is probably either a distinct species or a variation of geographic significance. If the coxal setal condition in *brennani* is as variable as in *Gahrliepia saduski*, it is of no remarkable significance.

Euschöngastia ikaoensis
(Sasa *et al.*, 1951)

Neoschöngastia ikaoensis Sasa, Sawada, Kano, Hayashi, and Kumada, 1951. Tokyo Iji Shinshi 26 (4): 8.

DIAGNOSIS: All palpal setae feathered. Palpal claw five-pronged. Galeal seta nude. Coxal setae 1–1–1. Sternal setae 2–2. Scutum about 2.5 times as wide as long. Sensillae pyriform. Two pairs of humeral setae. Scutal measurements of holotype: AW-61.5, PW-67, SB-24, ASB-18, PSB-15.5, AP-21, AM-30, AL-30, PL-39, S-33. Scutal measurements of a specimen from southern Korea: AW-62, PW-78, SB-28, ASB-22, PSB-15, AP-20, AM-28, AL-22, PL-39, sensillae missing.

DISTRIBUTION AND HOSTS: Known originally only from Japan from *Apodemus speciosus*. In Korea this was taken 17 miles southeast of Chorwon from *Apodemus agrarius*.

TYPE DATA: Holotype from *Apodemus speciosus*, Gumma Prefecture, Japan. Deposited at the Institute for Infectious Diseases, University of Tokyo.

Euschöngastia koreaensis n. sp.
Fig. 2

DESCRIPTION: *Gnathosoma:* All palpal setae feathered; palpal claw five-pronged. Galeal seta feathered. Cheliceral base and palpal femur with scattered light punctae. Chelicera with a subapical tooth or notch. *Scutum:* 2.5–3.0 times as wide as long; with a few light punctae. Sensillary bases behind a line connecting the posterolateral setae. Sensillae pyriform. Scutal measurements of holotype: AW-69, PW-86, SB-29, ASB-27, PSB-10, AP-17, AM-35, AL-45, PL-67, S-35. *Legs:* Coxal setae 1–1–1; seta on coxa III arising from the rear edge of the sclerotized part of the anterior margin of the coxa. Specialized (nude) setae as follows: Leg I, 2 genualae, 1 microgenuala, 2 tibialae, 1 microtibiala, 1 spur, 1 microspur, 1 subterminala, 1 parasubterminala, 1 pretarsala; Leg II, 1 genuala, 2 tibialae, 1 spur, 1 microspur, 1 pretarsala; Leg III, 1 genuala, 1 tibiala. *Setae:* Sternal setae 2–2. About 40 ventral setae behind coxa III, similar in character to sternal setae. Dorsal setae similar to scutal setae; dorsal setal formula: 2–12–12–12–6–6.

TYPE: Holotype from *Rattus rattus*, 17 miles southeast of Chorwon; November 15, 1951. Deposited in the U. S. National Museum. Paratypes from *Rattus norvegicus*, 7 miles southeast of Chorwon, and from *Apodemus agrarius*, 4 miles east of Inchon.

Trombicula (Leptotrombidium) palpalis
Nagayo *et al.*, 1919

Trombicula palpalis Nagayo, Mitamura, and Tamiya, 1919. Jikken Igaku Zasshi 3(4): 265–312.

Fig. 2 *Euschöngastia koreaensis*, n. sp.

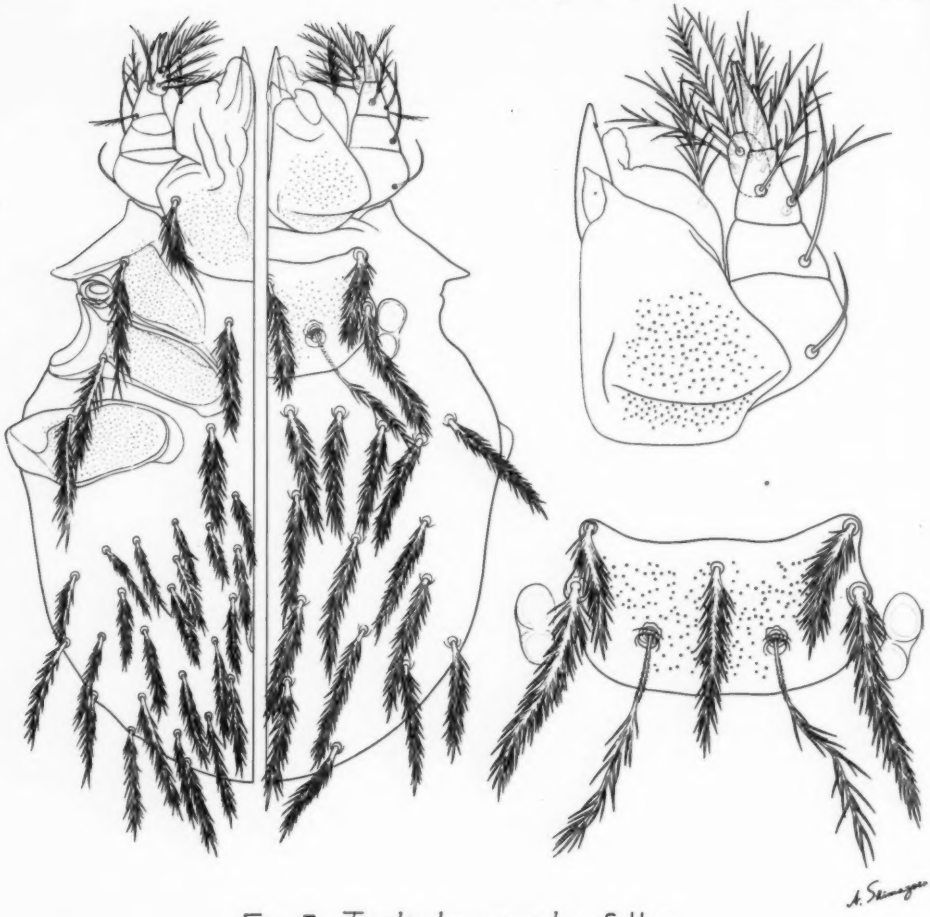

Fig. 3 *Trombicula orientalis* Schluger

DIAGNOSIS: Palpal femoral, genual, and lateral tibial setae nude; dorsal tibial and ventral tibial setae feathered. Galeal seta feathered. Rear corners of the scutum rounded; sensillary bases behind a line connecting the posterolateral setae. Bases of sensillae with minute barbs; sensillae plumose on the distal two thirds. Dorsal setal formula 2–10–10–10–8–4–2–2. Scutal measurements of a specimen from southern Korea: AW-60, PW-64, SB-27, ASB-27, PSB-13, AP-18, AM-42, AL-29, PL-53, S-49.

DISTRIBUTION AND HOSTS: From many localities in southern Korea from *Rattus rattus*, *R. norvegicus*, and *Apodemus agrarius*. This is the first record of *T. palpalis* occurring outside Japan.

TYPE DATA: From *Microtus montebelli*, Yamagata Prefecture, Honshu, Japan. A lectotype in the Institute for Infectious Diseases, University of Tokyo.

Trombicula (Leptotrombidium) orientalis Schluger, 1948
Fig. 3

Trombicula orientalis Schluger, 1948. Ent. Obozr. [Moscow] 30: 157.

DIAGNOSIS: Palpal femoral, genual, and lateral tibial setae nude; dorsal and ventral tibial setae feathered. Galeal seta feathered. Chelicerial base with numerous punctae. Seta on coxa III on anterior margin of coxa. Dorsal setal formula: 2–8–8–8–2–2. Scutum with posterior corners rounded; sensillary bases far behind a line connecting posterolateral setae. Sensillae with conspicuous, divergent basal barbs; plumose distally. Scutal measurements of a southern Korean specimen: AW-66, PW-67, SB-31, ASB-29, PSB-14, AP-18, AM-45, AL-40, PL-59, S-63.

DISTRIBUTION AND HOSTS: From many localities in southern Korea from *Apodemus speciosus*, *A. agrarius*, *Rattus rattus*, and *R. norvegicus*. Described from wild rodents from U.S.S.R.

TYPE DATA: Described from *Clethrionomys rufocanus* and *Apodemus speciosus*, South Shore, vicinity of Barabasha, U.S.S.R.

Trombicula (Leptotrombidium) pallida Nagayo *et al.*, 1919

Trombicula pallida Nagayo, Mitamura, and Tamiya, 1919. Jikken Igaku Zasshi 3: 265–312.

T. burnsi Sasa, Teramura, and Kano, 1950. Tokyo Iji Shinshi 67(10): 22.

T. murotoensis Sasa and Kawashima, 1951. Tokyo Iji Shinshi 68(12): 16.

DIAGNOSIS: Palpal femoral, genual, and lateral and ventral tibial setae nude; dorsal tibial seta feathered. Galeal seta feathered. Scutum more or less rectangular, with the posterolateral setae in the anterior part of the rounded posterior corners. Sensillary bases slightly behind posterolateral setae. Bases of sensillae with small but conspicuous and divergent basal barbs; distal two thirds plumose. Seta on coxa III well behind the anterior margin of the coxa. *T. pallida* is a highly variable species, especially with regard to the number of dorsal setae; but the short, bushy character of the dorsal setae and the nature of the scutum, sensillae, coxae, and gnathosoma are fairly constant. Scutal measurements of a specimen from southern Korea: AW-64, PW-72, SB-36, ASB-29, PSB-14, AP-21, AM-55, AL-38, PL-56, S-61.

DISTRIBUTION AND HOSTS: In Korea this species has been taken 13 miles southeast of Yonchon and 7 miles southeast of Chorwon, from *Rattus norvegicus* and *Apodemus agrarius*. Previously *T. pallida* was known only from Japan.

TYPE DATA: Lectotype selected from specimens collected by the original authors a-Yachi, Yamagata Prefecture, 1919, from *Mit crotus montebelloi*. Deposited at the Institute for Infectious Diseases, University of Tokyo.

Trombicula (Leptotrombidium) subintermedia n. sp.

Fig. 4

This species is allied to *Trombicula intermedia* Nagayo *et al.* of Japan and *T. lanceolata* Womersley of the tropical Orient.

DESCRIPTION: *Gnathosoma:* Palpal femoral, genual, and lateral and ventral tibial setae nude; dorsal tibial seta feathered. Galeal seta feathered. Palpal claw three-pronged. Chelicerial base and palpal femur with punctae. Chelicera with a dorsal subapical notch. *Scutum:* More or less rectangular, slightly more than twice as wide as long, with delicate punctae; rear corners rounded. Sensillary bases slightly behind a line connecting the posterolateral setae. Sensillae nude basally (minute barbs visible on some specimens), plumose distally. Scutal measurements of holotype: AW-70, PW-77, SB-31, ASB-27, PSB-20, AP-25, AM-50, AL-36, PL-63, S-67. *Legs:* Coxal setae 1–1–1; seta on coxa III considerably behind anterior margin of coxa. Specialized (nude) setae on legs: Leg I, 2 genualae, 1 microgenuala, 2 tibialae, 1 microtibiala, 1 spur, 1 microspur, 1 subterminala, 1 parasubterminala, 1 pretarsala; Leg II, 1 genuala, 2 tibialae, 1 spur, 1 microspur, 1 pretarsala; Leg III, 1 genuala, 1 tibiala. *Setae:* Dorsal setae moderately short and well provided with

Fig. 4 *Trombicula subintermedia*, n. sp.

barbs. Dorsal setae formula: 2–8–6–6–6–4–4. Sternal setae 2–2. About 44 small setae ventrally, behind coxae III.

TYPE DATA: Holotype from *Apodemus agrarius*, 2 miles southeast of Yonchon, November 27, 1951. Deposited in the U. S. National Museum.

COMMENTS: *T. subintermedia* can be separated from *T. intermedia* by the dorsal setal formulae: in *T. intermedia* this is 2–10–8–8–6–4–2, considerably more setae than in *subintermedia;* from *lanceolata* the new species differs in the sensillae being nude or almost so, whereas the original illustration of *lanceolata* shows numerous rather long sensillae, and the scutal measurements of *lanceolata* and *subintermedia* differ appreciably.

Trombicula (Leptotrombidium) hiranumai Kanda, 1942

Trombicula hiranumai Kanda, 1942. Chosen Nat. Hist. Soc., Jour. 9(37): 174.

DIAGNOSIS: Palpal femoral, genual, and lateral and ventral tibial setae nude; dorsal tibial seta feathered. Palpal claw three-pronged. Galeal seta feathered. Scutum rectangular, more than twice as wide as long, with the

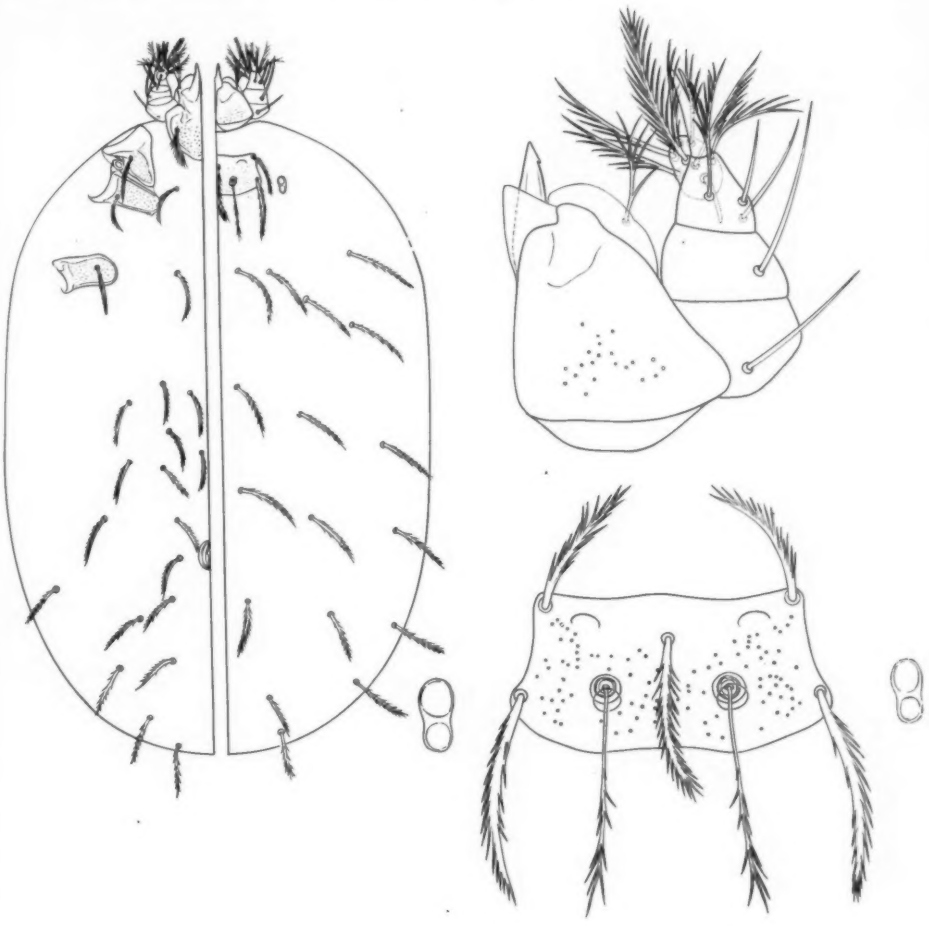

Fig. 5 *Trombicula myotis* Ewing

rear corners angulate. Sensillary bases in advance of a line connecting posterolateral setae. Sensillae basally nude, with plumose barbs distally. Dorsal setae arranged 2-10-8-8-7-4-2.

DISTRIBUTION AND HOSTS: Apparently known only from the original collection; not found in this survey.

TYPE DATA: From a cony, *Ochotona hyperborea*, from Konkyo-hokudo. The location of the type is not known.

COMMENT: This species resembles in some ways *T. akamushi* (Brumpt): *hiranumai* differs in having the scutum more than twice as wide as long in contrast to the scutum of *akamushi* which is less than twice as wide as long.

Trombicula (Leptotrombidium) myotis Ewing, 1929
Fig. 5

Trombicula myotis Ewing, 1929. Ent. News 40: 294.

DIAGNOSIS: Palpal femoral, genual, and lateral and ventral tibial setae nude; dorsal tibial seta feathered. Palpal claw three-pronged. Galeal seta feathered. Cheliceral base with a few punctae. Scutum with rear corners slightly rounded. Sensillary bases in advance of a line connecting posterolateral setae. Two crescent-shaped lines near the anterior margin of the scutum. Dorsal setae formula: 2–8–6–6–6–4–2. Scutal measurements of a specimen from southern Korea: AW-65, PW-71, SB-31, ASB-22, PSB-13, AP-24, AM-42, AL-40, PL-61, S-64.

DISTRIBUTION AND HOSTS: Previously recorded only from North America (see comments below), from various kinds of bats. In Korea *T. myotis* is known from Tobang-san from *Myotis* sp.

TYPE DATA: Cotypes from *Myotis lucifugus*, Mt. Katahdin, Maine, U. S. A. Deposited in the U. S. National Museum.

COMMENTS: Fuller (1948, Brooklyn Ent. Soc., Bul. 43: 106) has pointed out the similarity between *T. myotis* Ewing, 1929, and *T. russica* (Oudemans, 1902) of the Old World. We have not had the opportunity to compare our Korean specimens with *russica*, but they are very similar to North American specimens of *T. myotis* and, in our opinion, are not more than subspecifically distinct.

Trombicula (Leptotrombidium) subakamushi Schluger, 1948
Fig. 6

Trombicula subakamushi Schluger, 1948. Ent. Obozr. [Moscow] 30: 157.

DIAGNOSIS: All palpal setae nude (except setae on palpal thumb). Palpal claw three-pronged. Galeal seta branched. Coxal setae 1–1–1. Sternal setae 2–2. Nude setae on tarsi I and II and leg III as illustrated; spur on tarsus II slightly longer than that on tarsus I. Scutum rather rectangular, with the rear corners angulate, and the rear margin slightly undulate. Sensillary bases in advance of a line connecting posterolateral setae. Bases of sensillae nude; sensillae with scattered branches on the distal half. Scutal measurements of a specimen from southern Korea: AW-59, PW-78, SB-25, ASB-28, PSB-10, AP-28, AM-36, AL-28, PL-38, S-47.

DISTRIBUTION AND HOSTS: Previously reported only from the original collection. In Korea this species has been collected from *Myotis* sp. from Tobang-san.

TYPE DATA: From *Vespertilio superans* from Mt. Voroschilov, U.S.S.R.

COMMENTS: *T. subakamushi* resembles in some respects *T. insolli* Philip and Traub, 1950, a species described from bats from Selangor, Malaya, but the two are clearly distinct species: In *insolli* the galeal seta is nude and the scutum is approximately as long as wide.

Trombicula (Neotrombicula) tamiyai Philip and Fuller, 1950

Trombicula tamiyai Philip and Fuller, 1950. Parasitology 40(1, 2): 51.

DIAGNOSIS: All palpal setae feathered or branched. Galeal seta feathered. Cheliceral base and segments of palpi dorsally with numerous small punctae. Scutum rounded posteriorly; sensillary bases behind a line connecting posterolateral setae. Sensillae nude basally, with eight or more branches distally. One pair of humeral setae. Three mastitarsalae III. Scutal measurements of a specimen from southern Korea: AW-60, PW-73, SB-25, ASB-27, PSB-35, AP-17, AM-39, AL-42, PL-49, S-61.

DISTRIBUTION AND HOSTS: Previously known only from Japan. This species is exceedingly common in many localities in southern Korea and was taken mostly from *Rattus rattus* and *R. norvegicus*.

TYPE DATA: Holotype from *Microtus montebelloi*, Okiage Village, Yamagata Prefecture; September 17, 1920. Deposited in U. S. National Museum.

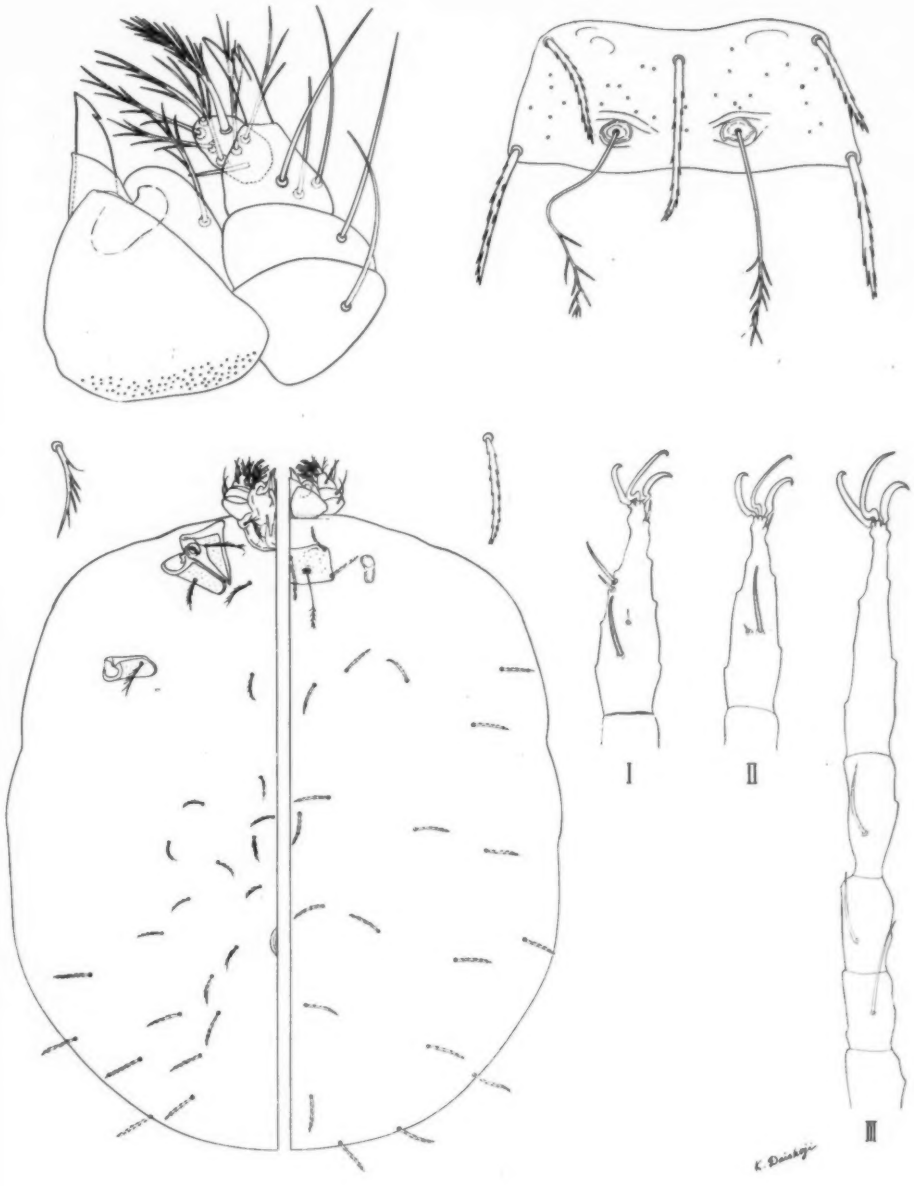

Fig. 6 *Trombicula subakamushi* Schluger

Trombicula (Neotrombicula) japonica
Tanaka *et al.*, 1930

Trombicula autumnalis japonica Tanaka, Kaiwa, Teramura, and Kagaya, 1930. Zentbl. f. Bakt. 116: 353.

DIAGNOSIS: Palpal femoral, genual, and ventral tibial setae feathered; lateral tibial seta forked or nude; dorsal tibial seta nude. Galeal seta usually nude, sometimes forked. Sensillary bases approximately on a line with posterolateral setae. Basal third of sensillae nude; distal two thirds plumose. Dorsal setae rather long; usually two pairs of humeral setae. Scutal measurements of a specimen from southern Korea: AW-81, PW-94, SB-33, ASB-35, PSB-31, AP-33, AM-65, AL-55, PL-75, S-88.

DISTRIBUTION AND HOSTS: Widely distributed and common in Japan; previously not known outside Japan. In Korea taken near Yonchon from *Rattus norvegicus and Apodemus agrarius*.

TYPE DATA: Described from *Microtus montebelloi*(?) taken at Yuzawa, Akita Prefecture, Japan.

Trombicula (Neotrombicula) nagayoi
Sasa *et al.*, 1950

Trombicula nagayoi Sasa, Hayashi, Sato, Miura, and Asahina, 1950. Tokyo Iji Shinshi 67(12): 14.

DIAGNOSIS: The gnathosomal features of *nagayoi* are similar to those of *japonica*, but there are usually fewer branches on the palpal setae. Sensillary bases distinctly forward of a line connecting posterolateral setae. Dorsal satae shorter than in *japonica* and with more barbs. A single pair of humeral setae. Scutal measurements of a specimen from southern Korea: AW-70, PW-91, SB-31, ASB-31, PSB-28, AP-33, AM-45, AL-40, PL-60, S-74.

DISTRIBUTION AND HOSTS: Previously known only from Japan where it is common and widely distributed. From southern Korea there are five specimens from 2 miles southeast of Yonchon from *Apodemus agrarius*.

TYPE DATA: From *Apodemus speciosus*, Yamanashi Prefecture, Honshu, Japan. Holotype deposited at the Institute for Infectious Diseases, University of Tokyo.

Trombicula (Neotrombicula) sp. Kanda

Trombicula sp. Kanda, 1942. Chosen Nat. Hist. Soc., Jour. 9(37): 174.

Kanda illustrated leg III of a chigger but did not identify or describe this species. From the presence of 1 mastifemorala III, 1 mastitibiala III, and 2 mastitarsalae III, this species belongs in the *microti* group of Brennan and Wharton. This species is possibly *T. pomeranzevi* Schluger, 1948, or *T. microti* Ewing, 1928, both of which have been taken in Manchuria by Dr. Kiyoshi Asanuma.

Fishes Killed by the 1950 Eruption of Mauna Loa
I. The Origin and Nature of the Collections

W. A. Gosline, V. E. Brock, H. L. Moore,
and Y. Yamaguchi[1]

The great volcano Mauna Loa plays many parts in the Hawaiian community. We are here concerned with its role as a fish collecting apparatus. The present paper, which is the first of a series that will deal with the the fishes made available to us by the 1950 eruption, is limited to an account of the general nature of our collections.

The Mauna Loa lava flows of June, 1950, reached the sea on the Kona coast of the Island of Hawaii at three main points (Fig. 1). The first two of these flows dwindled to almost nothing a short time after entering the water on the morning of June 2. The third flow has far greater significance for us. It entered the ocean somewhat to the south of the other two (at 19°16′N., 155°55′W.) on the afternoon of the same day. Surges of lava from this flow continued to pass into the sea in quantity through June 4 and in lesser amounts through June 7.

Whenever a heavy surge of lava hit the sea, a large amount of steam rose from the surface (Fig. 2). Between the peaks of the surges, at least during the later stages of the flow, the moving column of lava entered the sea quietly, unexpectedly resembling an escalator disappearing through the floor of a department store (Fig. 3). Apparently the failure to cause surface steam at such times was due to the cooling and hardening of the outer layer of the lava column into a water-impervious shell through which the rest of the lava flowed. (Such conduits, now hollow and sometimes extending for distances of more than a mile, are well-known features of the Hawaiian terrestrial landscape.) Since the molten material flowed continuously without ever filling this shell, it can be assumed that the lava was breaking out somewhere below. Such outbreaks presumably produced steam explosions which could be felt even in a skiff anywhere near the flow. However, no steam from these assumed outbreaks ever reached the surface, nor was this to be expected unless they had been very large or very near the surface.

The total amount of lava entering the sea from the 1950 eruption was estimated by Macdonald and Finch (1950: 1) at over 100 million cubic yards.

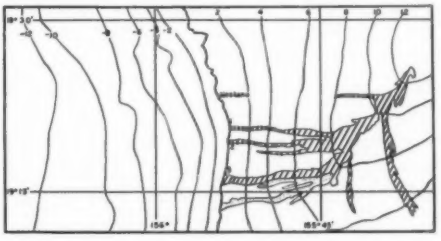

Fig. 1. Land areas covered by the Mauna Loa lava flows of 1919 and 1950. Heights above and below sea level given in thousands of feet. Diagonally hatched areas: 1950 flows; those that entered the sea are numbered in the sequence with which they reached sea level. Stippled area: 1919 flow. Redrafted in part from Macdonald and Finch.

[1] University of Hawaii; Territory of Hawaii, Division of Fish and Game; U. S. Fish and Wildlife Service; and Territory of Hawaii, Division of Fish and Game, respectively. Manuscript received January 17, 1953.

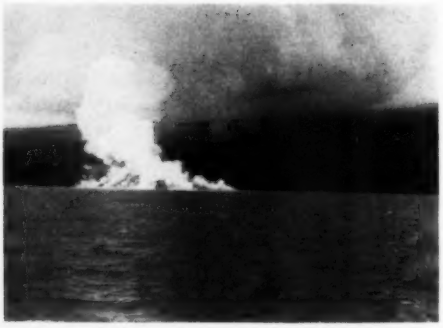

FIG. 2. Third lava flow reaching sea level on June 3.

Concerning sea conditions around the lava flow on June 2, Finch and Macdonald (1950: 6) state:

> By 5:00 P. M. a line of steaming water, marking the sub-sea course of the flow, extended to sea for about half a mile from the point where the . . . flow entered the ocean. Close to the shore and directly over the submerged flow, the water was boiling, and a semicircular area of hot turbulent water extended for a mile offshore. Many fish were killed and were seen drifting or were washed up on shore during succeeding days. The prevailing currents drifted the area of hot water southward.

On the morning of June 3 there was a "windrow" of dead fishes, 2 to 6 feet wide and extending as far as the eye could see, about 2 miles offshore from the flow. Inside this windrow, which marked a border between murky green and deep blue oceanic water, were other smaller, linearly arranged aggregations of dead fishes. At approximately half a mile from the point of entry of the lava, the water-cooled engine of the boat from which these observations were made became overheated.

By the afternoon of June 3 the windrows of fishes had broken up.

On June 6 the water in a roughly semicircular area several miles in radius around the point of entry of the lava was discolored and of dirty appearance. The relatively rare and scattered fish carcasses were found mostly toward the periphery of the disturbed area. Water a quarter of a mile from the flow was hardly warm, though a slick of upwelled hot water was still being formed closer in. The molten lava was still pouring into the sea continuously (Fig. 3), but in surges of greatly varying volume. The average width of the column entering the water at this time was perhaps about 30 feet.

On June 7 lava was entering the sea in greatly decreased volume and more or less intermittently, ceasing completely on this day or the next.

Four collections were made of the fishes brought to the surface of the sea by the 1950 lava flows. On the morning of June 2 Brock flew over the area where the lava was entering the water and made arrangements for collecting. In the afternoon of the same day Eugene Burke and Homer Hayes of the Territorial Division of Fish and Game took a small number of fishes. On June 3 the U. S. Fish and Wildlife Service vessel "Henry O'Malley," with Moore as scientist in charge, sent into the area a small boat from which collections were made in both the morning and afternoon. On the morning of June 6 Yamaguchi collected from a skiff. That afternoon Gosline, Homer Hayes, and Ed Keen took specimens from a sampan owned by Keen. On June 7 Hayes and Gosline returned to the area but found almost nothing.

Circumstantial evidence is rather strong that most of the fishes taken were brought to the surface during the early middle stages of the third flow. We know that the first stages of all three flows killed mostly inshore fishes, and we saw few of these. On the other hand, by June 6 relatively few fishes were coming to the surface, though live specimens were still occasionally seen. Furthermore, specimens in the June 6 collections often showed signs of more or less advanced decomposition.

Some of the fishes in these collections, particularly those taken on the first two dates, are in excellent condition. Others are not. Some of the latter were parboiled, some were partially decomposed, and some were both. The myctophids collected on June 6 gave the impression that if one looked at them in-

tently their scales would fall off. Nevertheless, the specimens in these four collections are probably in a better state of preservation than is most deep-water fish material.

Certain highly desirable data concerning our collections are unobtainable. For one thing, little can definitely be said about the depth from which these fishes came. Some of our specimens, such as the brotulids, are deep-water bottom forms. Others like the myctophids are bathypelagic. A few probably normally inhabit the surface layers of the open ocean. A very few are obviously inshore forms which had drifted into the area where we were collecting. The maximum depth at which our fishes were killed is likewise unknown. The most that can be said is that the known depth records for such fishes as *Opisthoproctus*, of which we took five specimens, indicate that at least some of our material is from rather deep water, presumably greater than half a mile.

We also do not know how representative our collections are of the total fish fauna living in the area. Four types of selectivity have probably restricted the representativeness of our sample. Two of these are due to our collecting methods and can be taken into account. First, we made no effort to collect the obviously inshore forms. Second, small fishes were almost completely missed because we took only what we could see and catch with a dip net from a boat. The other possible selective factors are: differential decimation

FIG. 3. The third lava flow entering the water several days later. Photograph by Jack Matsumoto.

among the species in the area and differential flotation among the species killed. These last two factors are impossible to evaluate, and the best that can be done is to point out their possible effects.

Death of these fishes may have been brought about by one or more of four causes: (1) the fishes may have been killed by simple overheating; (2) the lava entering the water may have introduced some directly or indirectly lethal chemical; (3) fishes with an air bladder may have been carried upward so rapidly by the upwelling water as to have caused overexpansion of this organ; and (4) the underwater explosions, caused by the breaking out of the molten lava from the conduits, may have caused some mortality. We do not have evidence that would make profitable a discussion of any of these possible causes of death. With any of them, however, it would seem likely that large fishes would be better able than smaller ones to move out of the way in time to avoid harm. The differential in decimation between large and small fishes may have been increased by the possibility that the water moving in to replace that which had upwelled carried with it small, weak swimmers from the surrounding region into the outbreak area.

Concerning the possibility of differential flotation, our only evidence is from the specimens we collected. With regard to these, two questions arise. What brought them to the surface, and, once there, why did they not sink back to the bottom? As to the first, one might suspect that the water heated by the lava would make its way through the water column above it to the surface, where it would spread out as a thin layer. Under such a hypothesis only the fishes from the area around the outbreaks would be brought to the top. Actually our collections contain epipelagic and a large number of bathypelagic fishes, as well as bottom forms. The presence of these pelagic species can best be explained by hypothesizing considerable mixing between the rising water and that around it. It does seem apparent that, regardless of the amount of mixing, fishes with a high specific gravity would be less readily transported to the surface than those with lighter bodies. Likewise, among fishes with the same specific gravity, those with a higher surface-volume ratio, e.g., small fishes, would be more easily carried in the upwelling water than those with a lower surface-volume ratio. It is possible, however, that not all the fishes we collected were originally brought to the surface by upwelled water, but rather that some of them were forced up after death by gases of decomposition.

This possibility leads into the question of why fishes were at the surface when we got there. Evidence from some of our specimens indicates that their air bladders became overexpanded and remained so after death, serving as floats. However, others show no expansion of an air bladder, and a large number of our specimens presumably do not even possess this organ. The presence of such fishes at the surface can best be explained by hypothesizing the formation of gases in parts of the body other than the air bladder. For example, the two brotulids we took on June 6 had the belly (but not the air bladder) greatly distended and empty. Most of our specimens, however, showed no abdominal distension. Whether decomposition gases and air bladder expansion can explain the presence of all our fishes at the surface seems open to question. Whatever the full explanation is, it must take into account the fact that, with the exception of two jellyfishes, we found no organisms other than fishes at the surface.

Our four collections together probably total 300 to 500 specimens distributed among more than 20 families. Perhaps a third of the individuals are myctophids. Except for the Myctophidae, and to a lesser extent the Sternoptychidae, none of the families is represented by more than a few specimens. Among groups unrepresented in our collections are sharks, flatfishes, and angler fishes.

In number of species our material would

seem to be much richer than the number of individuals might indicate. For example, each of the five brotulid specimens represents a different species. Such a representation indicates the variety of fish life that must exist in the deeper waters around Hawaii. Another piece of evidence bears on this same point. In 1922 Jordan reported on seven species collected from the sea around the point of entry of the 1919 lava flow (Fig. 1), six of which he described as new. Of these seven species, at least three and probably six were not taken by us.

There appear to be only two extensive reports on the deep-water fishes of the Central Pacific (Gilbert and Cramer, 1896; Gilbert, 1905). Both of these are based on dredge hauls made by the "Albatross" in Hawaiian waters. In the later paper, which summarizes the results, Gilbert recognizes 111 species taken below the 100-fathom line. Since 1905 occasional deep-water forms, mostly taken by fishermen, have been added to the Hawaiian fauna from time to time. The only previous paper based on Hawaiian fishes killed by a lava flow is that by Jordan (1922) mentioned above.

After the "Albatross" material, the 1950 lava-flow collections constitute the most important deep-water fish material yet taken in the Central Pacific. Their value is enhanced by the fact that, though there is some overlap, the 1950 collections by no means duplicate those taken by the "Albatross." For example, we took five species of brotulids whereas Gilbert did not record any; conversely, in another bottom-fish group—the flatfishes—Gilbert reported 13 species and we did not take any. Such examples, though extreme, again indicate the tremendous size of the fauna from which our samples were drawn.

It is planned to publish reports on the various groups in our collections in this journal as they are completed. The section on brotulids has been finished and appears elsewhere in this issue. Specimens of certain groups have been sent out to be worked up by others: the zeoids by Dr. George Myers, the myctophids and gonostomatids by Dr. R. L. Bolin, both of Stanford University, and the sternoptychids by Miss Janet Haig, of the Allan Hancock Foundation.

For constructive criticism and help in preparing the present paper we wish to thank Dr. R. L. Bolin, Dr. C. K. Wentworth, Mr. T. Cromwell, and various members of the University of Hawaii faculty.

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The Development of the Spermatophoric Mass of the Rock Lobster, *Parribacus antarcticus* (Lund)[1]

DONALD C. MATTHEWS[2]

INTRODUCTION

THE LITERATURE on the spermatophores of the tribe Scyllaridea is both superficial and scattered. Although cursory accounts of the extruded mass have appeared for both the Palinuridae and the Scyllaridae, few thorough histological studies have been made. This paper proposes to extend the knowledge of the biology of the common Hawaiian scyllarid, *Parribacus antarcticus* (Lund), through an account of its spermatophoric development.

Although Calman (1909: 290) in discussing the spermatophores of Crustacea fails to mention specifically the spermatophores of the Palinuridae [*sens. lat.*], he does state that in most Macrura the spermatozoa are enclosed in a sheath, forming a continuous cord-like mass. Moreover, he (*loc. cit.*) states that, "In *Scyllarus* and in the Anomura this is broken up into separate spermatophores attached by one end in a row on a strip of membrane."

Andrews (1912: 178), in referring to the spermatophoric mass of *Panulirus argus* Latreille, states:

> When cut the interior was white and full of holes or tubes. It suggested a very stiff cheese, but the minute cavities were not closed vesicles but short tubes . . . a careful examination of sections shows the short, tubular and somewhat branched cavities to be about one half millimeter in diameter and 1 or two long, separated by very fine walls of the dense white rubber-like material . . . the enveloping mass is white except on the surface where it is more or less black or grey according, apparently, to the length of exposure to water.

Although the change in consistency and color conforms to that observed by the author in the extruded mass of *Panulirus penicillatus* (Oliver), the observed "tubular cavities" were probably merely the result of sections cut through a highly contorted, continuous tube (Matthews, 1951: 365, fig. 10).

Andrews' description (*op cit.*, 183) of the external spermatophoric mass of *Parribacus antarcticus* is adequate, but again his reference to an "internal . . .matrix enclosing tubular cavities" is, as will be shown subsequently, erroneous.

Allen (1916), Fasten (1917), and Wilson (1948) described the change of color and consistency in the extruded spermatophoric mass of *Panulirus interruptus*, but did not investigate its development within the vas deferens. The observations of Crawford and De Smidt (1923) on *Panulirus argus* were also limited to the extruded spermatophoric mass.

The nonpedunculate spermatophore of *Panulirus penicillatus* (Oliver) (*vide* Matthews, 1951) resembles the spermatophores of the Macrura, but apparently no published accounts have verified Calman's statement (*op. cit.*) regarding the pedunculate spermatophores of the Scyllaridae.

METHODS AND TECHNIQUES

Twenty sexually mature *Parribacus antarcticus* (Lund) obtained from the Honolulu Aquarium during May, June, and July, 1952, were used in this study. Of the 18 male reproductive systems dissected, 6 were used to study the nature of the testes and the coiled vasa deferentia, 8 were vitally stained, and 4

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[1] Contribution No. 41, Hawaii Marine Laboratory.

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were serially sectioned. Of the two females obtained, only one possessed a spermatophoric mass; this was dissected and studied.

All dissections were made on living, nonanesthetized specimens immersed in sea water. The carapace was opened quickly, and the internal organs overlying the reproductive system were removed. The testis and coils of the vas deferens were then studied and sketched.

Two methods were employed in vital staining with aqueous solutions of neutral red and toluidin blue: (1) The stains were injected into the enlarged distal portion of the vas deferens (Fig. 1*d*) and allowed to permeate its contents proximally to the testis; (2) the vas deferens was removed from the body and placed in the stains. Both neutral red and toluidin blue were used in concentrations of 1:1,000 to 1:10,000. For the injection technique, solutions of approximately 1:1,000 to 1:5,000 were used; for the immersion technique, solutions of approximately 1:10,000 were used, and the vas deferens was allowed to remain in the stain from 10 to 30 minutes. The vas deferens was then removed from the stain and placed in sea water for subsequent study. Because injection tends to distend the walls and causes the stains to permeate the surrounding tissues, this technique was later abandoned in favor of the more easily controlled immersion method.

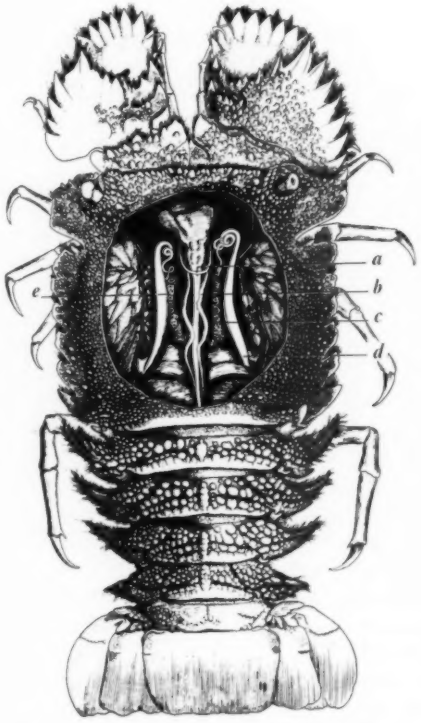

FIG. 1. Dissection of a mature male *Parribacus antarcticus* (Lund), drawn to show the position of the reproductive system. *a*, Transverse bridge; *b*, testis; *c*, coiled, proximal portion of vas deferens; *d*, straight, distal portion of vas deferens; *e*, hyaline line. (0.6×.)

The walls of the vasa deferentia were then teased open under a dissecting microscope and the vitally stained contents studied and drawn.

The vasa deferentia to be sectioned were removed quickly and placed in Bouin's fluid. After fixation, the tissues were washed in alcohol (70 per cent) and either cleared in dioxan and embedded in Tissuemat, cleared in toluene and embedded in Tissuemat, or placed in dioxan, cleared in methyl-benzoate (1 per cent celloidin added), washed in xylene, and embedded in Tissuemat (54–56°C.). None of these modifications was completely satisfactory for all regions of the vas deferens. All gave good preparations for sectioning the small proximal regions and poor preparations for sectioning the large, distal regions. This was due to the presence of the matrix (Fig. 10*c*) which upon dehydration had become extremely brittle. The distal region of the vas deferens could be sectioned only after immersing the block in water, although this resulted in some swelling of the connective tissue. The tissues were sectioned at 10 microns, stained in standard alumhaematoxylin, and counterstained with eosin.

The writer wishes to thank Mr. Spencer Tinker for supplying the specimens and Mr. James Park for making the illustrations.

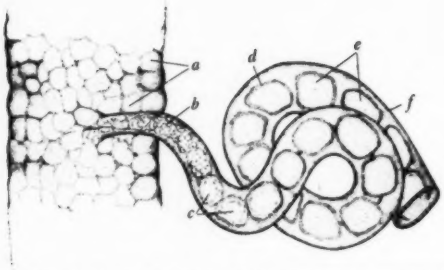

FIG. 2. A small portion of the testis and proximal vas deferens showing results of toluidin blue immersion technique. *a*, Sacculi; *b*, undifferentiated spermatogenic substance; *c*, moniliform portion; *d*, capsule of ampulla; *e*, distinct ampullae; *f*, thin wall of vas deferens. (15×.)

DISCUSSION

The testes (Fig. 1*b*), when freed from overlying tissues, resemble those of *Panulirus penicillatus* (Matthews, 1951: 360) in that they form an elongate H, the right and left sides joined by a transverse bridge (*a*) just posterior to the junction of the pyloric region of the stomach to the intestine. As in *P. penicillatus*, the testes lie contiguous to the digestive tract. Occasionally one, less frequently both, of the portions of the testes anterior to the bridge bifurcate, although the posterior region is unaltered. The dissecting microscope reveals the testis as a highly coiled, continuous, thin-walled tube into which innumerable small sacculi open (Fig. 2*a*). The sacculi of different regions appear indistinguishable as to number and size. Both testes are enveloped by a delicate mesentery and penetrated by numerous blood vessels.

The vas deferens (Fig. 1*c*) which emanates from the testis is an extremely small, highly coiled tube which, increasing in diameter distally, finally emerges as a large tube (*d*) opening on the coxopodite of the fifth periopod. A hyaline line (*e*) traverses most of the length of the otherwise chalky, opaque tube, marking the position of the internal typhlosole (Fig. 10*d*). This hyaline line is prominent only in the distal enlarged portion (Fig. 1*d*). The numerous coils of the proximal portion are not constant either as to number or direction of their turns, as none of the vasa deferentia studied was identical.

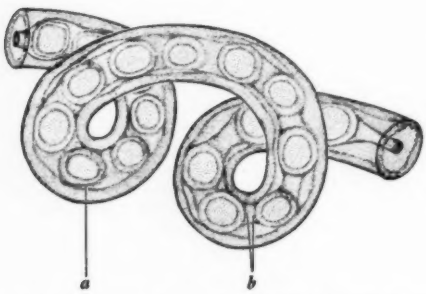

FIG. 3. A small portion of the vas deferens immediately distal to the region illustrated in Figure 2, showing results of toluidin blue immersion technique. *a*, Secretion which envelops the already encapsulated ampullae; *b*, sheath between successive ampullae. (15×.)

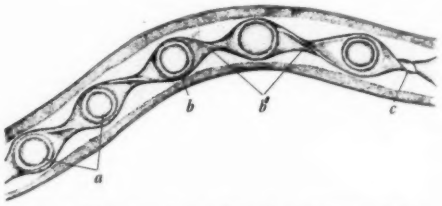

FIG. 4. Diagram of a small portion of the vas deferens immediately distal to the region illustrated in Figure 3, showing the results of immersion technique. *a*, Successive encapsulated ampullae; *b*, sheath surrounding encapsulated ampulla; *b'*, ribbon-like sheath between successive ampullae; *c*, twisted, ribbon-like sheath. (15×.)

All regions of the vas deferens fail to exhibit muscular contractions and are quiescent even when exposed quickly. There were no intermittent contractions which are so characteristic of certain vasa deferentia. Whereas the persistent mobility of the vas deferens of *Dardanus asper* (Matthews, 1953: 258) may be related to its stamina, the apparent immobility of the vas deferens of *P. antarcticus* may be related to its debility. The cessation of contractions in the altered, exposed vas deferens obscures the mechanical aspect of spermatophoric development. Vital staining is there-

fore invaluable in discerning the effects of contractions in the unaltered vas deferens.

Figure 2 illustrates the results of immersing a small portion of the testis and the proximal region of the vas deferens in toluidin blue. Here the thin wall of the vas deferens (*f*) affords rapid penetration of the stain, and the absence of the matrix (Fig. 10*c*) makes clear the developing spermatophore. The undifferentiated spermatogenic substance (Fig. 2*b*) is seen as it enters the vas deferens. As it traverses the vas deferens, this undifferentiated spermatogenic substance becomes moniliform (*c*) and, acquiring a capsule (*d*), separates into distinct ampullae (*e*).

FIG. 5. Diagram of a dissected portion of the vas deferens immediately distal to the region illustrated in Figure 4, showing the results of immersion technique. *a*, Widely separated encapsulated ampullae; *b*, highly twisted, ribbon-like sheath. (15×.)

Figure 3 illustrates the results of the immersion technique on a small portion of the vas deferens immediately distal to the region illustrated in Figure 2. A new sheath (*a*) now envelops the already encapsulated ampullae and occupies the space between successive ampullae (*b*).

The results of the immersion technique on a small portion of the vas deferens immediately distal to the region illustrated in Figure 3 are shown in Figure 4. The successive ampullae (*a*) are now more widely separated. The sheath (*b*) which envelopes the already encapsulated ampullae is thin and between successive ampullae is now ribbon-like (*b'*). In the distal portion of this region the ribbon-like sheath connecting successive ampullae is twisted (*c*).

Figure 5 is a diagram of a dissected portion of the vas deferens immediately distal to Figure 4. The ampullae (*a*) are widely separated

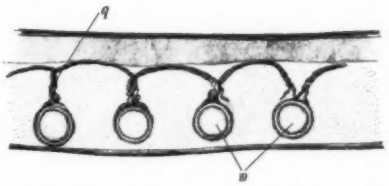

FIG. 6. Diagram of a dissected portion of the vas deferens distal to the region illustrated in Figure 5. *a*, "Elevated" ampullae; *b*, entwined, twisted ribbons. (15×.)

and the connecting sheath (*b*) is more highly twisted.

A diagram (Fig. 6) of a dissected portion of the vas deferens distal to Figure 5 shows the ampullae (*a*) less widely separated and "elevated" by the entwining of their already twisted connecting sheaths (*b*).

Serial sections substantiate what vital staining has so far revealed and enable one to determine the origin of the various secretions. Figure 7 is a cross section through the vas deferens in the region indicated by *b* of Figure 2. The undifferentiated spermatogenic mass (*a*) occupies the almost circular lumen (*b*). The wall of the vas deferens is here composed

FIG. 7. A cross section through the vas deferens in the region indicated by *b* of Figure 2. *a*, Undifferentiated spermatogenic mass; *b*, circular lumen; *c*, wall of vas deferens; *d*, epithelial layer. (134×.)

FIG. 8. A cross section through the vas deferens in the region indicated by *c* of Figure 2. *a*, Crypt-like fold of the epithelium; *b*, spermatids; *c*, secondary spermatocytes; *d*, capsule secretion; *e*, primary spermatocytes. (106×.)

of a thin muscular and connective tissue layer (*c*), and a thin layer of epithelium (*d*). In Figure 8 the spermatophoric capsule is being laid down by a secretion (*d*) of the crypt-like folds of the epithelium (*a*). It is significant that spermatogenesis is taking place. Primary spermatocytes (*e*), secondary spermatocytes (*c*), and spermatids (*b*) are clearly discernible.

Figure 9, a cross section through the vas deferens in the region indicated by *a* of Figure 3, shows the secretion of the sheath (*b*) around the already encapsulated ampulla (*c*).

Figure 10 is a stereogram of the vas deferens through the region indicated by *d* of Figure 1. The ampullae (*a*) are "elevated" and the already twisted connecting ribbon-like sheaths are entwined (*b*). The matrix (*c*), the copious secretion of the typhlosole (*d*), has forced the spermatophores to lie opposite the hyaline line (*e*).

Figure 11 is a drawing of a portion of a female sternum (*a*) and a partially dissected spermatophoric mass. The hard, darkened outer portion of the matrix (*b*) envelops the less hardened matrix (*c*) which contains the ampullae (*d*) attached to doubly twisted peduncles.

The undifferentiated sperm mass emanates from the testis probably because of the continuous activity of the germinal epithelium lining the sacculi. In the proximal portion of the vas deferens, not more than 4 or 5 millimeters long, this undifferentiated spermatogenic material is both moved along and molded into a continuous moniliform mass, presumably by the muscular contractions of the wall. In this same region of the vas deferens the crypt-like folds of the epithelium produce a secretion which forms the thick capsules of the now distinct ampullae.

As the encapsulated ampullae traverse the vas deferens, the epithelium produces another secretion, the sheath, which both surrounds the already encapsulated ampullae and fills the intervening spaces. Less than 1 centimeter of the proximal vas deferens is traversed before the portions of this sheath lying between adjacent ampullae are compressed into a thin, delicate ribbon, probably by contractions of the wall of the vas deferens. Because of the immobility of the dissected vas deferens, the process was not observed.

The chalazal twisting of the connecting ribbons probably is due to the rotations of the

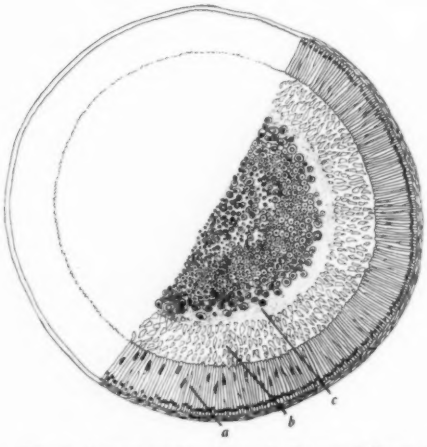

FIG. 9. A cross section through the vas deferens in the region indicated by *a* of Figure 3. *a*, Epithelium; *b*, sheath secretion which surrounds the encapsulated ampullae; *c*, capsule. (125×.)

ampullae as the coils of the proximal region of the vas deferens are traversed. The "drawing together" of the ampullae probably is also the result of the shortening of the ribbons due to this twisting. Moreover, the entwining of the already twisted ribbons to form the stalk or peduncle is also a result of this process.

The secretion of the typhlosole now surrounds the already formed spermatophores and by its accumulation forces the continuous, pedunculate spermatophores against the wall of the vas deferens opposite the hyaline line.

As the spermatophores traverse and finally accumulate in the enlarged distal portion of the vas deferens, the process of spermatogenesis is completed. The primary spermatocytes have undergone two successive divisions, and the spermatids have metamorphosed into mature spermatozoa.

It is at this stage of development that the spermatophoric mass is placed on the sternum of the female and, as described by Andrews (*op. cit.*), darkens and hardens when it is exposed to sea water. The dissected spermatophoric mass reveals not a series of tubular cavities but a continuous thread-like ribbon (or two ribbons if both vasa deferentia have participated) from which the pedunculate spermatophores extend.

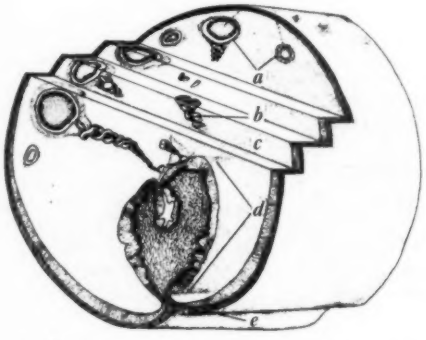

FIG. 10. Stereogram of the vas deferens in the region indicated by *d* of Figure 1. *a*, "Elevated" ampullae; *b*, entwined, twisted ribbons; *c*, matrix; *d*, typhlosole; *e*, hyaline line. (25×.)

FIG. 11. A partially dissected spermatophoric mass taken from the sternum of the female. *a*, Portion of sternum; *b*, hard, dark portion of matrix; *c*, soft, light portion of matrix; *d*, ampullae attached to doubly twisted peduncles. (3.5×.)

It should be recalled that only one female was observed which possessed the spermatophoric mass. The actual process of sperm liberation was not observed, but the scratched, hardened matrix, together with the specialized claws (*vide* Andrews, *op. cit.*), suggest a mechanical method.

The results of this investigation may lead to speculations on the systematic position of the Scyllaridae. Although the spermatophores of *Parribacus antarcticus* are intermediate between those of the nonpedunculate spermatophores of a palinurid (*Panulirus penicillatus*) and the pedunculate spermatophores of a pagurid (*Dardanus asper*), an inference that *Parribacus antarcticus* is intermediate between these forms is not warranted. Anatomical, embryological, and serological evidence should accompany such spermatophoric evidence, and this should be drawn from many species representing many genera.

The present study on the spermatophores of *P. antarcticus* should serve to question the interpretation placed on the function of the peduncle. The origin of the seemingly significant peduncle may have been only the fortuitous occurrence of mechanical and physiological activities of the vas deferens with little regard for the elevation of the ampullae and the subsequent dispersal of the spermatozoa. Certainly, in *P. antarcticus* the peduncle serves no such useful purpose, inasmuch as the hard enveloping matrix prevents the ampullae from being held "aloft."

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Bibliographic Notes on G. Forster's "De plantis esculentis insularum oceani australis" (1786)

E. D. MERRILL[1]

THERE ARE CERTAIN overlooked aspects of G. Forster's small book of 80 pages issued in 1786. The first is that there were two editions, one the doctorate thesis printed at Halae ad Salam in 1786 and a reprint of this with a new title page issued in Berlin in the same year; and the second aspect is that various new names, with very ample descriptions, were herein published anterior to their appearance in Forster's *Prodromus*, in which only very short diagnoses were provided.

No date closer than the year appears on either edition, both bearing the legend: "Datum Vilnae Lithuanicae, anno MDCCLXXXVI." I have detected no differences in the technical parts, pages 25–80, but the Halle edition (the thesis) carries a 14-line footnote on page 19 which was eliminated in the Berlin issue, whereas the former bears at the end of the introduction, page 20, the name Georgivs Forster, and the latter D. Georgivs Forster. One can only conclude that the Halle issue appeared first and the Berlin edition somewhat later. The eliminated footnote is interesting, and, as it throws some light on what happened, it seems desirable to reproduce it here:

Dedarat in pater optimus, flagitanti amico ut aliquot centurias plantarum ex Itinere relatarum, magni nominis Viro et modo non montes auri pollicenti ea tamen lege atque omine, dono concederet, ne iis quisquam uteretur, ad descriptiones ex siccis speciminibus parandas; quum scilicet easdem Pater et Ego juncta opera evulgare nobis proposuissemus. Verum in *Supplemento Plantarum Systematis Vegetabilium a* CAROLO *a* LINNE Filio Brunsvigae 1781, edito, in qualibet pagina plantis Oceani Pacifici, Botanophili mirantur iam nunc nomen Equitis Baeck, adscriptum; qui nunquam hoc mare adiit.

Sic Vos non Vobis
Hos ego versiculos feci, tulit alter honores!

It was customary in the eighteenth century often to add to labels or to statements added to herbarium sheets (and thus mentioned in publications) the name of the donor rather than the name of the collector, when a set of specimens had been received as a gift from an intermediary. Abraham Baeck (or Bäck) was one of Linnaeus' most intimate friends and was accustomed to acquire botanical material from time to time and to present the specimens to Linnaeus. It was unquestionably Baeck who purchased a set of duplicates of the Forster Collection. As Linnaeus died early in January, 1778, these specimens found their ultimate resting place in the herbarium of the son. This in turn was acquired by Sir James Edward Smith when he purchased the entire Linnaean Herbarium; but the herbarium of the younger Linnaeus was distributed into the Smith Herbarium, now maintained separately at the Linnaean Society in London. Willdenow continued this system as he built up his large herbarium which is, as to specimens, the basis of his greatly amplified edition of Linnaeus' *Species plantarum*, 1797–1824. Another strange practice that was continued up to at least the middle of the nineteenth century in some botanical centers was the writing of the name of the species and that of the collector on the herbarium sheets and the discarding of the original labels and notes (if any).

Thus it is that in the younger Linnaeus, *Supplementum plantarum* (1781) the references

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to his new species based on Forster collections from Tahiti, New Zealand, and elsewhere are such that one would infer that Baeck was the collector. Examples are *Aeschynomene coccinea* L.f., and *Melaleuca villosa* L.f., "Equ. Bäck," *Anthoxanthum crinitum* L.f., "Eques Bäck," etc., as well as included J. R. and G. Forster species credited to Baeck as their source although the specimens were collected by the Forsters.

Surely the younger Forster was wisely advised in eliminating the footnote above quoted when the Berlin issue of his minor work was printed. After all, from the liberties he took with numerous Solander names, he certainly had little justification in criticizing the actions of others whose work impinged slightly on his own tardily developed field. There are at least hints that there were some rather caustic letters from Forster to the younger Linnaeus, but I have not followed this lead, such data being irrelevant now.

In our day, when sets of duplicates are sold by collectors, the situation is different than it was in earlier times, because now no reservations are made or implied. It is safe to assume that the sets of Forster specimens recorded by de Candolle as being at Paris and at the University of Kiel were actually sold by the older Forster, because of his financial straits following the London debacle in 1777 caused by his breaking of his signed agreement not to publish a journal of Cook's second voyage. This restriction was neatly by-passed: the son, 17 years old when the expedition left England, is the indicated author, as nobody thought of requiring him to sign an agreement not to publish an account of the trip. It seems to be clear that the father contributed materially to it, or at least guided his son in the preparation of the text. At any rate the younger Forster's account of the voyage was published in both English (London, 1777) and German (Berlin, 1778), the former several months before Cook's official journal was issued in London in 1777.

This strange act alienated all the Forsters' friends and supporters in England and naturally offended the Admiralty. The situation became so acute that neither father nor son was able to secure remunerative employment in that country. Thus they were forced to return to Germany, their situation being ameliorated by the elder Forster's receiving an appointment at the University of Halle in 1780. A brief summary of this now more or less forgotten episode appears in the biographical sketch of J. R. Forster included in volume fifteen of the Rees Cyclopedia (1810). In it there is a beautiful example of British understatement regarding this episode: "...the father was supposed to have had a considerable share in it." Stansfield in 1935 summarized the episode thus: "This action of the Forsters, which was admittedly sharp practice, prevented their obtaining further posts in this country, and for a time they both fell on lean times"—another example of British understatement. This is no reflection on the ability of the individuals concerned, as they were both highly educated, able, and productive; but today we would say that they were distinctly unethical. However, for practical purposes the action taken by them in London in underhandedly breaking the signed agreement appertaining to the journal prevented much further detailed consideration of results of their field work in the Pacific, because at that time it was only in London that library facilities and extensive reference collections were available to them. What the younger Forster later accomplished on the Pacific collections was in no respect noteworthy, and what was published came approximately a decade after the London debacle. I have not elaborated this episode in detail because certain documents are not available to me, but William Wales (1778) apparently took some part in the controversy, to which the younger Forster responded (1778).

I had noted, incidentally, that most of the new species of Forster f. which appeared with very ample descriptions in *De plantis esculentis* (1786) appeared also in the *Prodromus* (1786)

with exasperatingly short diagnoses consisting of but one or two to three or four (rarely five) lines. The introduction is dated at Vilna, Lithuania, June 30, 1786. It was published in Göttingen. Moreover, in the *Prodromus*, in almost every case where the same new species was involved, there was a reference to the binomial and to the page where it appeared in *De plantis esculentis*. This is proof that the latter work was printed before the *Prodromus* was published. Because the descriptions of new species appearing in *De plantis esculentis* are in general very ample, in contrast to the greatly abbreviated *Prodromus* diagnoses, I was naturally surprised to note that in botanical literature nearly all references are to the *Prodromus* rather than to the earlier *De plantis esculentis*.

The priority of issue of *De plantis esculentis* over the *Prodromus* is again proved by the reviews of both works appearing very shortly after the small volumes were published. In the *Göttingische Anzeigen von gelehrten Sachen* (volume three for 1786, the September 25 number, pp. 1538–1542) there is an ample review of *De plantis esculentis* (the Berlin issue, not the original thesis), while the *Prodromus* has an equally ample review in the November 13 number (pp. 1816–1820). This is a spread of over 1½ months. The net result of these investigations is a series of corrections to the entries in *Index Kewensis*, in which the references are to the *Prodromus*. One striking thing indicating the unfinished character of the *Prodromus* is that, among approximately 75 vascular cryptogams so briefly diagnosed as to be scarcely described, more than 30 of the new species are not even localized; and the vast region from which the specimens came extends from Easter Island and the Marquesas to Tahiti, the Friendly Islands, New Zealand, New Caledonia, and the New Hebrides. The real importance is that the *Prodromus* entries are merely one- to three-, rarely four- to five-line diagnoses, whereas the earlier published descriptions in *De plantis esculentis* are, for the most part, in great detail.

In the following lists, the dagger (†) preceding a specific name indicates a correction to the *Index Kewensis* entries and the asterisk (*) an unlisted binomial.

Areca †sapida Soland. ex Forst. f., Pl. Esculent. 66, 1786, Prodr. 94, 1786. New Zealand. = *Rhopalostylis sapida* (Soland ex Forst. f.) Wendl. & Drude. The data appertaining to this New Zealand species in the first reference are notes rather than a technical description; the second entry is a nomen nudum.

Avicennia †resinifera Forst. f., Pl. Esculent. 72, 1786, Prodr. 45, 1786. New Zealand. This is currently but erroneously reduced by most workers to *A. officinalis* L., a species with flowers 10 to 15 mm. in diameter, its type from Ceylon, and which is not known farther to the southeast than New Guinea. The New Zealand form with very much smaller flowers, 2.5 to 5 mm. in diameter, is *A. marina* (Forsk.) Vierh. var. *resinifera* (Forst. f.) Bakh. (Bul. Jard. Bot. Buitenz. III. 3: 103, 210, pl. 16, 1921).

Cocos *rubra Forst. f., Pl. Esculent. 67, 1786, *nom., nota*, sub *Areca sapida* Soland. Tonga. = *Cocos nucifera* L. Forster f. merely stated: "Huius forte generis [Areca] est *Niu-gula*, (Cocos rubra), Palma, cuius *Cookius* meminit in Tonga insula, *itineris novissimi* tomo I. p. 332." The reference is to Cook's account of his third voyage (1784: 332). His *neeoogula*, or red coconut, is mentioned as a kind of cabbage tree not distinguishable from the coconut, with an insipid tenacious kernel, the fruits scarcely 2 inches long assuming a reddish cast when ripe. In spite of the indicated small size of the fruit, this is certainly a teratological form of *Cocos nucifera* L.

Convolvulus †chrysorhizus (Soland.) ex Parkinson, Jour. 37, 1773, *nom., nota;* Soland. ex Forst. f., Pl. Esculent. 55, 1786, *nom., nota ampl.*, Prodr. 89, 1786, nom. nud. = *Ipomoea batatas* (L.) Poir. In his long discussion Forster f. gave the range

as from Easter Island to New Zealand, considering it correctly as merely a form or variety of *Ipomoea batatas* (L.) Poir., the common sweet potato. He compiled other information from Rumphius, indicating the significance of the names used for it in the Moluccas before about 1680 (*castila*, *uby-*, *ima-*, and *lutu-castila*, and *camotes*), these names having been introduced there from the Philippines. However, the sweet potato was first recorded from Guam, Cebu, and the Moluccas by Pigaletta when these islands were first discovered by Magellan in 1421, a too often overlooked record. The name *camotes* is of Mexican origin.

Coriaria †sarmentosa Forst. f., Pl. Esculent. 46, 1786, descr. ampl., Prodr. 71, 1786, diagn. New Zealand. The first reference is to a very detailed one-and-one-third page description, the second to a four-line diagnosis.

Crataeva †religiosa Forst. f., Pl. Esculent. 45, 1786, descr. ampl., Prodr. 35, ampl., Prodr. 35, 1786, diagn. Tahiti and the Society Islands. The first reference is to a detailed, 40-line description, the second to less than a full line diagnosis. Here Forster f. appropriated Solander's name as his own, as he did in many other cases.

Dracaena †indivisa Forst. f., Pl. Esculent. 64, 1786, descr. ampl., Prodr. 24, 1786, diagn. New Zealand. = *Cordyline indivisa* (Forst. f.) Steud. The contrast here is a two-line diagnosis in the *Prodromus* to a 60-line detailed description and discussion in the original place of publication.

Ficus †aspera Forst. f., Pl. Esculent. 36, 1786, descr. ampl., Prodr. 76, 1786, diagn. New Hebrides (Tanna). In contrast to the two-line diagnosis in the *Prodromus*, the earlier description cited consists of about 15 lines and was based on specimens from Tanna. In the *Prodromus*, Namoka is also listed; this is Nomuka in the Tonga group.

Ficus †granatum Forst. f., Pl. Esculent. 37, 1786, Prodr. 76, 1786. New Hebrides (Tanna). The first published description consists of about 20 lines, the diagnosis published later in the same year consists of three lines.

Lepidium †oleraceum Forst. f., Pl. Esculent. 69, 1786, descr. ampl., Prodr. 46, 1786, diagn. New Zealand. The first published description is a greatly detailed one of 35 lines; the diagnosis published later in 1786 consists of two lines only. Limited to New Zealand and neighboring islands.

Lepidium †piscidium Forst. f., Pl. Esculent. 70, 1786, Prodr. 46, 1786. Huaheine (easternmost of the Leeward group, Society Islands) and "botanices insula ad novam Caledoniam adjacente." Solander had this written up in his unpublished manuscript under a different specific name from Eimeo, Huaheine, Ulaietea, Tahiti, and Otaha, and observed: ". . . copiosissime autem in insulis depressionibus Oceani Pacifici." The original and first published description by Forster f. is in great detail, about 30 lines; the later published diagnosis of two lines only, but in the *Prodromus*, between Botanices insula and Huaheine, he added Teautea. Botanices insula is between New Caledonia and the Isle of Pines.

Maba †major Forst. f., Pl. Esculent. 54, 1786, descr., Prodr. 92, 1786, nom. nud. Friendly Islands. The first published description is a rather cursory one consisting of 11 lines, but therewith Forster f. records having observed the species on Tongatabu, Namoka [Nomuka], Euwa, Hopai, and other islands in the Friendly group.

Solanum †aviculare Forst. f., Pl. Esculent. 42, 1786, Prodr. 18, 1786. New Zealand. The original and first published description is a detailed one of nearly 30 lines, the later diagnosis consists of two lines only. Known also from Tasmania, Australia, and Norfolk Island.

Solanum †viride (Soland.) ex Parkinson, Jour. 38, 1773, *nom., nota;* Solander ex Forst. f., Pl. Esculent. 72, 1786, *nom., nota*, Prodr. 89, 1786, nom. nud. Society Islands. = *S. uporo* Dunal. Parkinson provided no

description, and the little that Forster f. wrote about it was taken entirely from the former's data. Parkinson's entire statement about the Tahitian *pouraheitee* was, "The leaves of this plant, baked, are eaten as greens." *Solanum anthropophagorum* Seem. (1862) is a synonym.

Spondias †dulcis (Soland.) ex Parkinson, Jour. 39, 1773; Forst. f., Pl. Esculent. 33, 1786, descr. ampl., Prodr. 34, 1786, diagn. Society and Friendly Islands. The detailed description in *De plantis esculentis* consists of about 50 lines, the species is there credited to both the Society and the Friendly Islands; "in Taheiti frequentissima." In the *Prodromus* only the Society Islands were mentioned, and the diagnosis was limited to six words. Here Forster appropriated Solander's unpublished binomial (Solander MS., p. 257). There is a Parkinson plate and also a Forster one. These documents are at the British Museum (Nat. Hist.). Among all the new species of Solander actually considered by Parkinson in 1773, the latter's descriptive notes on this *Spondias* present, I judge, his nearest approach to a botanical description. If this be not accepted, then the next older name is *Mangifera pinnata* L. f. (1781) = *Spondias pinnata* (L.f.) Kurz; and the next validly published name, *Spondias cytherea* Sonn. (1783), was based on material grown in the Île de France from seeds introduced by Commerson direct from Tahiti. (Commerson was the botanist on Bougainville's expedition that visited Tahiti in 1768 between Captain Wallis's discovery of the island in 1767, and Captain Cook's first visit in 1769).

Terminalia †glabrata (Soland.) ex Parkinson, Jour. 40, 1773, *nom., nota;* Forst. f., Pl. Esculent. 52, 1786, descr. ampl., Prodr. 74, 1786, diagn. Society and Friendly Islands. The species as first amply described by Forster f. in his *De plantis esculentis* (nearly 50 lines) is a distinct one, confused by some workers with the very different *T. catappa* L. His later diagnosis in the *Prodromus* consists of four words only.

Tetragonia †halmifolia Forst. f., Pl. Esculent. 67, 1786, descr. ampl., Prodr. 39, 1786, diagn. New Zealand and the Friendly Islands. = *Tetragonia expansa* Murr. (1783). The usually cited later publication of the binomial consists of 12 words; the earlier published detailed description occupies about 40 lines of type.

SIXTEEN OVERLOOKED "BINOMIALS" IN MUSA

It is somewhat disconcerting to note that on pages 29 to 32 of George Forster's *De plantis esculentis* there are 16 validly published but unlisted *Musa* binomials, all based on the data recorded by Rumphius in 1747 (pp. 130–133). Although Rumphius is mentioned in the discussion, there is no direct reference to the *Herbarium Amboinense* under any of the binomials; yet the sequence of the arrangement of the taxa are the same in both works, and the Malaysian native names listed by Forster f. are the same as those recorded by Rumphius. Thus there is no doubt as to the source of the younger Forster's data. All of these "species" are forms of the *Musa paradisiaca* = *Musa sapientum* complex, unless one or two of them might eventually prove to belong with *M. troglodytarum* L. (*M. fehi* Brotero). Rumphius was not misled but spoke of these as varieties. We are now assured by the geneticists (and this is apparently correct) that both the Linnaean "species," *Musa paradisiaca* L. and *M. sapientium* L., are derivatives from *Musa balbisiana* Colla and *M. acuminata* Colla. In these modern days it is improbable that any taxonomist would think of applying a binomial to any of these *Musa* forms, yet Forster f. ennobled all of them in 1786 by assigning binomials and providing Latin descriptions. They are:

Musa *acicularis Forst. f., Pl. Esculent. 30, 1786.

Musa *coarctata Forst. f., l. c., 32.

Musa *coriacea Forst. f., l. c., 30.

Musa *corniculata Forst. f., l. c., 29. This eliminates *M. corniculata* Lour. (1790), and *M. corniculata* Kurz (1878).
Musa *dorsata Forst. f., l. c., 31.
Musa *exsucca Forst. f., l. c., 29.
Musa *fatua Forst. f., l. c., 32.
Musa *granulosa Forst. f., l. c., 31.
Musa *lunaris Forst., f., l. c., 32.
Musa *mensaria Forst. f., l. c., 30. This replaces *M. mensaria* Moench. (1794).
Musa *papillosa Forst. f., l. c., 32.
Musa *pumila Forst. f., l. c., 32.
Musa *punctata Forst. f., l. c., 31.
Musa *purpurascens Forst. f., l. c., 31.
Musa *regia Forst. f., l. c., 31.
Musa *tetragona Forst. f., l. c., 30.

These 16 binomials appertain to forms occurring in the Moluccas and in other parts of Malaysia. They are strangely hidden in a little book otherwise appertaining strictly to Polynesia, New Zealand, and very slightly to the New Hebrides and New Caledonia.

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On the Genus *Felisacus* Distant (Heteroptera; Miridae; Bryocorinae)

T. E. WOODWARD[1]

THE GENUS *FELISACUS* Distant includes 16 species of elongate, transparent winged bugs of the subfamily Bryocorinae, with a mainly tropical and subtropical distribution in the Western Pacific and Indian Ocean areas. Species are recorded from Madagascar, Seychelles, Ceylon, Burma, Malaya, Formosa, Philippines, Guam, Borneo, Java, Amboina, New Guinea, Australia, New Zealand, Fiji, and Samoa. In the course of this paper a division of the genus into two or possibly three species-groups or subgenera is discussed. One of these groups is mainly northern Pacific in distribution (S.E. Oriental region), the second mainly southern Pacific (apparently centred on the Australasian region), while the third (and tentative) group borders mainly the Indian Ocean.

The only host plants recorded for species of this genus are ferns, and all the evidence indicates a preference for and probable restriction to ferns as food plants of these bugs. Extensive sweeping over a period of several years in New Zealand has yielded no specimens of *F. elegantulus* from any other plants but low-growing, bracken-like ferns, and then only in rather damp, stream-side localities shaded by trees, where a large series, including nymphs as well as adults, has been collected in a very limited area. This last preference may perhaps be correlated with a tropical origin of the genus in regions where the characteristic vegetation cover is rain-forest. The whole subfamily Bryocorinae, indeed, is distributed preponderantly, though not exclusively, in the wet tropics and is represented most strongly in Central and South America.

The fern-frequenting habit of numbers of species belonging to other genera of Bryocorinae is well known and probably applies also to a good proportion of the species for which no host records are yet available. The habit seems commonest in the tribe Bryocorini, members of the tribes Odoniellini and Monaloniini apparently having a very diversified host range. By no means all Bryocorini are fern-dwellers, but the tribe as a whole does show an unusual preference for ferns, which seem from the records to be neglected by most other mirids. The Bryocorinae are generally regarded as a morphologically rather primitive mirid group and, while the preference of many of them for a relatively archaic group of plants may be coincidental, there is the possibility of its being a retained preference. This, of course, touches on highly hypothetical ground, but the host preference of insects is an interesting and fundamental, if still at present rather obscure, problem, and it seems to the writer that this case suggests some possibilities that are susceptible of test. Useful evidence might be accumulated by the identification, wherever possible, of the host plants of *Felisacus* and of other genera of Bryocorinae. It would be interesting, for example, to see whether there is any general phylogenetic correlation between the species and genera of Bryocorinae and the genera or families of plants on which they feed, or whether the preference for ferns, where it exists, extends no further than the nature of

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the food and other products of metabolism of ferns as contrasted with those of higher plants.

There is what appears to be a somewhat analogous case among the Hemiptera in the archaic homopteran family of Peloridiidae, which require a substratum of continuously moist mosses or lichens. In this instance both the general type of host plant and the associated high humidity seem to be necessary. It might be possible to test to what extent the host preference of any particular species of Bryocorinae is due to a dependence on the host plant itself or upon the habitat conditions in which the host normally lives. Such preference may be related not only to food needs but also to requirements of oviposition. The writer has seen no reference to the oviposition habits of those Bryocorinae living on ferns, but from what is known of their life histories it would seem likely that they insert their eggs in the food plant.

Acknowledgments

I wish to express my gratitude to Professor R. L. Usinger, College of Agriculture, University of California, for the opportunity of studying and describing the material of *F. amboinae* and *F. usingeri*, and for the gift of specimens of *F. magnificus* Distant and *F. ochraceus* Usinger (paratype); also to Dr. R. I. Sailer, U.S. Department of Agriculture, and Dr. R. Kellogg, Director, and Dr. E. A. Chapin, Curator of the Division of Insects, U.S. National Museum, for the loan of a paratype and another determined specimen of *F. philippinensis* Hsiao, from the latter institution. I am much indebted to Dr. W. E. China, Department of Entomology, British Museum (Nat. Hist.), for valuable information and advice on the systematics of the group. I also with to thank Mr. B. A. O'Connor, Government Entomologist, Department of Agriculture, Suva, Fiji, for the loan of material of *F. filicicola* (Kirkaldy); Mr. A. W. Parrott, Curator of Insects, Cawthron Institute, Nelson, New Zealand, for the loan of the specimens of *F. elegantulus* (Reuter) from Nelson; and Mr. J. R. Henry, Keeper of the Macleay Collection, University of Sydney, Mr. J. M. Letchford, of Brisbane, and Mr. F. A. Perkins, Head of the Department of Entomology, University of Queensland, for the gift or loan of Australian specimens of the latter species. For the kind provision of transport and other assistance in collecting material I am indebted to Dr. E. J. Reye, Brisbane, Queensland, and Dr. R. A. Cumber, of the Entomological Research Station, Nelson, New Zealand; and for the identification of host ferns to Dr. L. H. Millener, Department of Botany, Auckland University College, and Miss J. W. Herbert, Department of Botany, University of Queensland.

Genus FELISACUS Distant

Liocoris Motschoulsky, 1863. Bul. Soc. Imp. des Naturalistes de Moscou 36(2): 86 (preoccupied by *Liocoris* Fieber, 1858).

Felisacus Distant, 1904. Fauna Brit. India, Rhynchota 2(2): 434, 438 (new name for *Liocoris* Motsch.). Poppius, 1912. Acta Societatis Scientiarum Fennicae 41(3): 181–182 (redescription).

Hyaloscytus Reuter, 1905. Öfversigt af Finska Vetenskaps-Societetens Förhandlingar 47 (5): 1–2.

Felisacus elegantulus (Reuter)

Hyaloscytus elegantulus Reuter, 1905, Öfv. Finska Vetensk.-Soc. Förhandl. 47(5): 2, fig. 1.
Felisacus elegantulus (Reuter) auct.

STRUCTURE: Width of head across eyes less than 1.5 times the length (15.75:12; 17:12); interocular space nearly or quite twice as wide as eye (8:4.5; 8:4). Basal 0.25 to 0.33 of head cylindrical, forming a collum separated from rest of head by an annular constriction, in front of which the crown is moderately raised and convex; from constriction, sides convexly diverging to posterior margins of eyes, where head is 0.75 as wide as across eyes; basal collum about 0.8 as wide as head at base of

eyes and nearly 0.66 as wide as across eyes (11:17). Rostrum reaching to middle coxae. Antennae with segment I cylindrical, with long, erect, sparse hairs; II more slender than I, pubescent; III and IV very slender and curved; II about 0.25 longer than I (35:28); III about 1.5 times length of I (43:28); IV about 0.56 the length of I (16:28).

Pronotum in mid-line nearly twice as long as head (23:12); rather more than 0.25 wider across posterior angles than long (30:23), 2.5 times as wide as across anterior collar (30:12), and 0.75 as wide again as head across eyes (30:17); in mid-line, anterior lobe, including collar, shorter than posterior lobe (10:13), the constriction between them coarsely and deeply punctate toward sides, with the two mesial punctures set well forward; posterior lobe strongly raised from constriction, evenly convex from side to side except for shallow sublateral depressions just inside posterior shoulders; lateral margins of shoulders nearly straight, sides of basal lobe of pronotum in front of them markedly sinuate; base broadly and only moderately emarginate in front of scutellum, exposing more or less of mesoscutum, outside scutellum shallowly sinuate. Scutellum with disc nearly flat, smooth, with long, erect, pale hairs; sides incised and then expanded before apex, which is acute and depressed; scuto-scutellar punctures deep, ovoid, oblique.

Hemelytra about twice as long as abdomen; costal margins of corium nearly straight and parallel in closed position, slightly incurved apically, more than twice as long as total width of pronotum (58:24; 51:22) and about three times as long as cuneus; outer margin of inner division of clavus thickened and raised, with a row of long, pale, erect hairs.

Male genitalia as in Fig. 4*a*, *b*.

Length: Female, 4.2–4.7 mm. Male, 4.0–4.3 mm.

Width across hemelytra: Female, 1.1 mm. Male, 1.0 mm.

COLOUR: Head and pronotum shining, yellowish brown, sometimes tinged with green. Often two more or less distinct red marks above inner margins of antennal bases, sometimes also a red mark on groove at base of tylus and on each side of head, particularly on basal collum. Eyes dark brown or reddish brown. Rostrum light brown; labrum black. Antennae dark brown; first segment shining, lighter brown or mahogany; first and second segments pale at extreme base; antenniferous tubercles pale. Posterior shoulders of pronotum dark brown to black. Scutellum uniformly pale yellowish or greenish brown, except for the narrowly dark lateral margins. Hemelytra highly translucent, colourless, except for embolium, which is semiopaque, usually pale green in life; veins strong, brown or greenish brown; margins of embolium and of inner division of clavus and inner margin of corium between clavus and membrane brown to black; corium, clavus, and cuneus glassy, extremely finely and shallowly punctate; membrane very finely and irregularly rugulose, clear, iridescent, with margins narrowly infuscated. Hind wings colourless; veins wide, pale amber, sometimes tinged with pale green. Legs yellowish brown, paler ventrally and on coxae and basal part of femora, which are often light green; tarsi infuscated. Abdomen usually green in life, fading after death to pale yellowish brown.

A colour form exists differing in the following respects from the above description: The red coloration is much more developed; red marks above antennal bases fused as a complete transverse band, red mark on frontal depression very pronounced, red lines on sides of head longer and more definite, extending from eye to pronotum; eyes and first segment and apex of second segment of antennae markedly reddish; dorsal surface of femora and tibiae red; prothoracic shoulders not or scarcely infuscated. Of the specimens examined, 10 of the 26 females and 23 of the 28 males from New Zealand are of this colour form, and one of the ten males and one of the six females from Australia. Both colour forms have been captured together in the

same area. An occasional specimen with well-developed red markings has also heavily infuscated pronotal shoulders.

NYMPH: (Late instar—probably fifth—captured with adults at Puketona, N. Z.) Colour of dried specimen brown, with well-developed red markings as in the second colour form described above. Length, exclusive of anal tube, 2.2 mm.; length of anal tube, 0.37 mm. Head shorter than in adult, vertical in front between antennae. Eyes dark brown, almost touching pronotum. Width of vertex between eyes, 0.2 mm.; width including eyes, 0.45 mm. Legs and antennae long and slender. Length of antennal segment I, 0.8 mm., II, 0.95 mm., III, 1.3 mm.; segment II more slender than I, and III and IV than II. Pronotum with a median groove, sides gradually and smoothly curved, widening posteriorly. Hemelytra extending about midway along abdomen. Anal tube very long, slender, cylindrical, base red, apex pale.

SPECIMENS EXAMINED: New Zealand: 5 females, 2 males, 1 nymph, swept from low ferns (*Pteris tremula* R. Br.) in damp, shaded locality near stream, Puketona, North Auckland, February 12, 1949; 2 females, 1 male, from low ferns at Paihia, Bay of Islands, North Auckland, February 13, 1949; 22 males, 18 females, 29 nymphs, swept from low ferns (*Pteris tremula* R. Br.) in shaded locality beside stream, Whirikino, near Foxton, Manawatu (Wellington Province), January 27, 1951; T. E. Woodward. Three males, 1 female, on fern, Nelson, April 27, 1950, E. S. Gourlay. Australia: 1 male, Illawarra, New South Wales (Macleay Collection). One female, Brisbane, June 3, 1932; 2 females, 1 male (no data, but almost certainly from neighbourhood of Brisbane); Dept. of Entomology Coll., University of Queensland. Eight males, 2 females, 1 nymph, swept from low ferns (*Hypolepis muelleri* Wakefield) in shaded locality beside stream, Dunwich, Stradbroke I., Moreton Bay, Queensland, June 2, 1951, T. E. Woodward. One female, Brisbane, March 29, 1952, J. M. Letchford.

F. elegantulus was described from Victoria, Australia. The present records considerably extend its known distribution, north to New South Wales and Queensland and east to both the North and the South Islands of New Zealand.

Felisacus filicicola (Kirkaldy)

Hyaloscytus elegantulus Reuter, var. *filicicola* Kirkaldy, 1908. Proc. Linn. Soc. N.S.W. (2) 33(2): 376–377.

Felisacus filicicola (Kirkaldy) Knight, 1935. Ins. Samoa 2(5): 200.

STRUCTURE: Head width across eyes nearly 1.5 times the length (17.5:12); interocular space nearly twice as wide as eye (8.5:4.5). Basal 0.17 of head cylindrical, forming a collum separated from rest of head by a sharp annular constriction, in front of which the crown is moderately raised and convex; from constriction, sides convexly diverging to posterior margins of eyes, where head is rather less than 0.75 as wide as across eyes (12:17.5); basal collum about 0.83 the width of head at base of eyes (10:12) and over 0.5 the width across eyes (10:17.5). Rostrum reaching to middle coxae. Antennae with segment I cylindrical, with long, erect, sparse hairs; II more slender than I, pubescent; III and IV very slender, curved; length of I:II::28:35.

Pronotum in median line over 1.5 times length of head (21:12); about 0.25 wider across posterior angles than long (26:21), about 2.3 times as wide as across anterior collar (26:11), and 1.5 times as wide as head across eyes (26:17.5); in mid-line, anterior lobe, including collar, shorter than posterior lobe (9.5:11.5), the constriction between them coarsely and deeply punctate toward sides, with the two middle punctures set well forward; posterior lobe strongly raised from constriction; both lobes evenly convex from side to side except for sublateral depressions inside posterior shoulders; shoulders with lateral margins nearly straight, sides of pronotum sinuate in front of them; base distinctly and roundly

emarginate in front of scutellum, widely exposing mesoscutum. Scutellum moderately raised, disc nearly flat, smooth, with sparse, longish, erect pale hairs, apex declivous, sides incised just before apex; two deep transverse punctures on scuto-scutellar suture.

Hemelytra long; costal margins of corium nearly straight and parallel, rather more than twice as long as total length of pronotum (50:23); outer margin of cuneus rather more than 0.33 as long as corium (17.5:50); outer margin of inner division of clavus raised and thickened, with a row of long erect hairs.

The male genitalia are described by Usinger, 1946: 69.

Length: Female, 4.2 mm. Width across hemelytra, 1 mm.

COLOUR: Shining above; head, venter, pronotum, and first segment of antennae fulvous; second antennal segment dark reddish brown. Eyes dark brown. Scutellum fulvous brown. Margins of inner division of clavus brown. Embolium semiopaque, yellowish brown, reddish brown at apex, inner and outer margins narrowly black. Corium with a fuscous band alongside apical third of margin of clavus. Apical margin of corium as far as cuneus dark brown. Rest of corium clear, transparent. Cuneus reddish brown. Membrane clear except for very narrowly dark margins and fuscous brown vein; iridescent and finely and irregularly rugulose. Coxae, trochanters, and base of femora yellow; tarsi fuscous; rest of legs shining brown.

This species displays a rather similar colour variation to that seen in *elegantulus*. Kirkaldy (1908) states that "the colouring of the body is somewhat variable, being often suffused with red; the pronotum may be immaculate, or the postero-lateral angles may be more or less widely fuscous."

SPECIMENS EXAMINED: 1 male (damaged), 1 female, Kadavu, Fiji Is., July 25, 1938, R. A. Lever.

F. filicicola is very close to *F. elegantulus* (Reuter), but differs in its darker colour (head and pronotum fulvous, scutellum fuscous, cuneus reddish brown), the pronotum in median line shorter relative to head, with base more deeply excavated, less expanded, and narrower in proportion to length, to anterior width, and to width of head across eyes.

Felisacus amboinae n. sp.

Figs. 1, 2

STRUCTURE: Head across eyes nearly 1.5 times the length (16:11); interocular space just over 1.5 times as wide as eye (7:4.5). Eyes large, as seen from above rather longer than postocular part of head (6:5). Basal 0.2 of head cylindrical, forming a collum separated from rest of head by a sharp annular constriction, in front of which the upper surface is strongly raised and convex; from constriction, sides convexly diverging to posterior margins of eyes, where head is 0.75 as wide as across eyes (13:17.5); basal collum about 0.75 as wide as head behind eyes (0.75–0.79) and over 0.5 as wide as across eyes (9.25:16, 10:17.5). Rostrum reaching to middle coxae. Antennae with segment I cylindrical, with long, erect, sparse hairs; II more slender than I, pubescent; III and IV very slender and curved; length of I:II::26:32.

Pronotum with median length over 1.5 times that of head (male, 19:11; female, 22:13); 0.16 to 0.2 wider across posterior angles than long (male, 23:19; female, 26:22) and about 2.33 times as wide as across anterior collar (male, 23:10; female, 26:11.5); in mid-line, anterior lobe, including collar, equal or very nearly equal in length to posterior lobe, the constriction between them coarsely and deeply punctate toward sides, with the two middle punctures set well forward; posterior lobe strongly raised from constriction; both lobes evenly convex from side to side except for sublateral depressions inside posterior shoulders; shoulders with lateral margins nearly straight, sides of pronotum moderately sinuate in front of them; base distinctly emarginate in front of scutellum, somewhat angularly concave in middle, widely exposing mesoscutum. Scutellum moder-

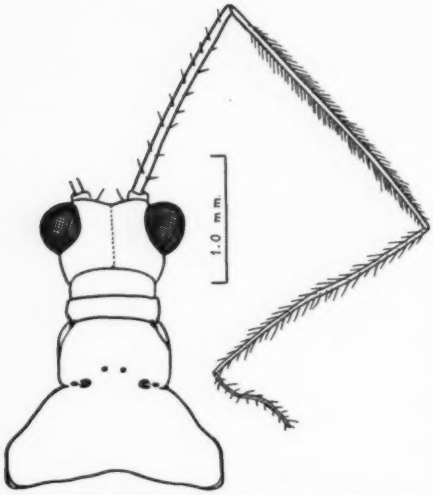

FIG. 1. *Felisacus amboinae* n. sp. Head and pronotum.

ately raised, smooth, with sparse, longish, erect pale hairs; two deep punctures on scutoscutellar suture.

Hemelytra long; costal margins of corium nearly straight and parallel, slightly over twice as long as total length of pronotum (48:23); outer margin of cuneus rather less than 0.33 as long as corium (14:45, 15:48). Outer margin of inner division of clavus raised and thickened, with a row of long, pale, erect hairs.

Length: 3.75 mm. Width across hemelytra: Male, 0.8 mm.; female, 0.95 mm.

COLOUR: Shining above. Head, pronotum, and scutellum yellowish brown. Head with red markings anteriorly, along inner margins of eyes, and narrowly in mid-line. Eyes reddish brown or reddish black. Antennae with segment I red or reddish brown, II red or reddish black, III and IV black. Rostrum yellowish brown. Sides of anterior division of pronotum sometimes red. Base of pronotum inside posterolateral angles more or less infuscated. Swollen outer part of anterior lobe of scent-gland spout red. Legs yellow; apex of femora and base of tibiae red, the red colouring sometimes extending along entire upper surface or even whole of tibiae and as a narrower dorsal line on femora; tarsi infuscated at apex. Whole of cuneus coloured, orange or orange-red, with inner margin usually widely and costal margin more narrowly red. Embolium red at apex and narrowly red or reddish brown along costal and inner margins. Inner half of clavus red, at least on margins; outer half translucent, pale. Inner margin of corium along apex of clavus more or less widely dark brown or black. Apical margin of corium as far as cuneus red, with adjacent area more or less infuscated. Membrane with margins narrowly infuscated; veins testaceous, more or less tinged with red. Rest of hemelytra clear hyaline. Veins of hind wings brown. Ventral surface of body yellowish brown. Dorsal surface of abdomen red.

TYPES: Holotype male, allotype female, 1 paratype male, Amboina (E. Indies), F. Muir. Deposited in the California Academy of Sciences.

This is the species noted by Usinger (1946: 70).

F. amboinae belongs to the *elegantulus* group of species (see below) and is perhaps most closely related to *ochraceus* Usinger, from Guam. It is distinguished from the latter, however, by marked differences in colour, by the less protuberant eyes, by the basal emargination of the pronotum being less widely rounded and more angulated in the middle, and by the proportionately somewhat shorter cuneus. It differs from *filicicola* (Kirkaldy) in colour, the smaller size, the eye wider in proportion to interocular space, the head

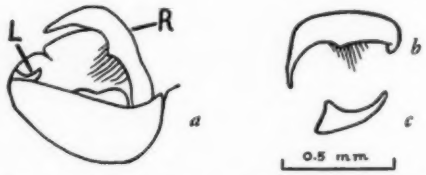

FIG. 2. *Felisacus amboinae* n. sp. *a*, Apex of male abdomen, posterior aspect (R, right clasper; L, left clasper); *b*, right clasper, posteroventral aspect; *c*, left clasper, lateral aspect.

across eyes narrower in proportion to width immediately behind eyes, where head is rather more expanded and wider also in proportion to basal collum, the posterior lobe of pronotum relatively somewhat shorter in mid-line and wider at base, and the cuneus proportionately rather shorter. From *elegantulus* (Reuter) it differs in colour, the smaller size, the eye wider in proportion to interocular space, basal collum of head narrower in proportion to width both behind eyes and across eyes, pronotum somewhat shorter in mid-line relative to head, with base proportionately wider. From *nigricornis* Poppius (not seen) it differs in colour and the relatively shorter pronotum and first antennal segment, and from *jacobsoni* Poppius (not seen) in colour, the smaller size, the relatively shorter hemelytra and first antennal segment, the pronotum shorter, more declivous, and less narrowed from base to apex.

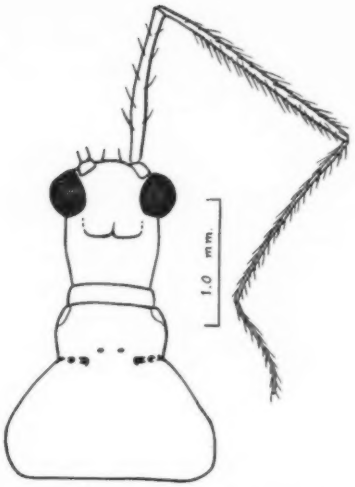

FIG. 3. *Felisacus usingeri* n. sp. Head and pronotum.

Felisacus usingeri n. sp.

Fig. 3

STRUCTURE: Head long and narrow, scarcely wider across eyes than long (14:13); as seen from above, not concave in front, anterior margin between antenniferous tubercles nearly straight, slightly convex, about 0.25 width across eyes (3.5:14); 0.4 as wide again across eyes as immediately behind eyes (10:14), thence gradually and slightly narrowed to base of head, where 0.9 as wide as behind eyes; no collum or annular subbasal constriction; crown with a transverse depression behind and between eyes, scarcely extending beyond level of their inner margins; seen from above, postocular part of head distinctly longer at sides than length of eye (7:5), with sides nearly straight, slightly sinuate behind middle. Eyes moderate, each over half as wide as interocular space (3.75:6.5). Seen from the side, eye equal in height to length of the vertical, apical (subocular) part of head from ventral margin of eye to base of rostrum (7:7). Antenniferous tubercles short, scarcely projecting beyond apex of head. Rostrum reaching middle coxae; relative lenghts of segments I–IV, 5:5:11:16. Antennae shorter than body (85:110); segment I shorter than pronotum (18:22.5), about 0.25 longer than width of head (18:14), moderately swollen at basal third and tapering to just before apex, widening slightly at extreme apex; segment II slender, cylindrical; III and IV extremely slender, curved; I with sparse, erect, pale hairs, other segments pubescent; proportionate length, I–IV, 18:27:26:14.

Pronotum about 0.75 as long again as head (22.5:13); collar short, about 0.09 total length of pronotum; posterior lobe half as long again as anterior lobe, including collar (13.5:9); the constriction between them deeply punctate, the two mesial punctures set distinctly forward; posterior lobe strongly convex, considerably raised above constriction, more shortly declivous toward base; base nearly straight, only very feebly emarginate before base of scutellum; over twice as wide across posterior shoulders as across collar (24.5:10.5) and rather wider than total length (24.5:22.5); sides of posterior lobe in front of shoulders straight, evenly converging toward constriction. Scutellum rather strongly raised, with

sparse, erect, pale hairs; smooth except for two large punctures on basal margin.

Hemelytra long; the costal margin of corium feebly arcuate, especially posteriorly, less than twice as long as pronotum (42:22.5); the cuneus more than 0.33 as long as corium (17.5:42).

Length: Female, 3.8 mm. Width across hemelytra, 0.9 mm.

COLOUR: Head, pronotum, and scutellum shining, pale yellowish brown. Eyes reddish brown. First antennal segment yellowish brown; second segment and apex of first dark reddish brown; third and fourth black. Clavus pale amber, margins of inner division darker yellowish brown. Embolium slightly tinged with amber; yellow at apex; margins, especially at apex, very narrowly brown. Inner margin of corium, from just in front of apex of clavus to inner basal angle of cuneus, infuscated brown; rest of corium colourless. Cuneus nearly colourless, faintly tinged with amber; outer margins narrowly dark. Membrane colourless; veins pale. Rostrum, tibiae, apex of femora, undersurface of head and thorax pale yellowish brown. Tarsi infuscated at apex. Remaining segments of legs and venter of abdomen yellowish white.

TYPE: Holotype female, Los Banos (Luzon, Philippine Is.), July 17, 1936, R. L. Usinger. Deposited in the California Academy of Sciences.

This species was noted by Usinger (1946: 72).

F. usingeri belongs to the *magnificus* group of species and appears to be closest to *philippinensis* Hsiao, differing in the paler colour; the rather smaller size; the narrower head across eyes in proportion to length of head, width behind eyes, and width of pronotal base; the much shorter second and third antennal segments; and the longer rostral segments I–III (4:4:8 in *philippinensis*). *Usingeri* resembles *magnificus* Distant in the long, narrow head; from this species, however, it differs strikingly in colour, the pattern being very characteristic in *magnificus*, in the shorter antenniferous tubercles and the more convex and much narrower anterior border of the head between them (in *magnificus*, interantennal width: width across eyes::4.5:15), in the three basal segments of the rostrum being longer in proportion to the fourth (in *magnificus*, 3:3:8.5:18), height of eye equal to subocular part of head (much greater in *magnificus*, 8:5), the proportionately shorter first antennal segment (in *magnificus*, I:II::22:25), the posterior lobe of pronotum narrower at base in proportion to anterior collar (in *magnificus*, 27:10.5).

From *crassicornis* Usinger the new species differs in its paler colour, in the much longer and narrower head, the eyes wider in proportion to interocular space, the proportionately longer second antennal segment, the pronotum longer in proportion to head, with apical collar proportionately shorter, the cuneus longer in proportion to corium. From *pulchellus* Poppius (not seen) it differs markedly in colour, the wider eyes in proportion to interocular space, and the relatively much longer second antennal segment; and from *longiceps* Poppius (not seen) in colour and in the relatively much shorter first and fourth antennal segments.

The measurements and figures of *magnificus* given in this paper are derived from a specimen collected in Amboina, E. Indies (F. Muir, June, 1908), and kindly supplied to me by Dr. R. L. Usinger, who had provisionally identified it as *magnificus*. This species was described from Tenasserim (Distant, 1904: 439, fig. 284). Topotypic material has not been available, so that no further comparison has been possible. However, the appearance of *magnificus* is strikingly characteristic, and the present specimen agrees with Distant's figure and with his description as far as it goes. In view of the presence of *elegantulus* in both Australia and New Zealand, the occurrence of *magnificus* so far from its type locality does not seem so surprising. Little is known of the extent and methods of distribution of the species of this genus. It

would be interesting to test the possibility of the eggs being inserted into and transported in fern stems (e.g., among packing material).

SPECIES GROUPS OF FELISACUS

The species of *Felisacus* fall into at least two and possibly three groups.

To the *magnificus* group belong *magnificus* Distant, 1904 (Tenasserim, Burma, and Amboina, E. Indies), *pulchellus* Poppius, 1915*b* (Philippine Is.), *longiceps* Poppius, 1915*b* (Formosa), *philippinensis* Hsiao, 1944 (Philippine Is.), *crassicornis* Usinger, 1946 (Guam), and *usingeri* n. sp. (Philippine Is.). This group is characterised by the subbasally swollen first antennal segment, by the nearly straight, scarcely emarginate base of the pronotum, and by the neck-like postocular part of the head gradually narrowing to the base, without a cylindrical basal collum sharply and completely constricted from a wider region behind the eyes. In *magnificus*, *philippinensis*, and *crassicornis*, at least, the right clasper of the male has the form of a curved rod, slender throughout its length, not considerably widened and flattened basally; the left clasper is nearly straight and only feebly curved on its outer margin; the right clasper is slightly knobbed or spatulate at apex, and either the right or the left clasper, or both, may give off a shorter or longer internal branch; ventral margin of apex of abdomen narrowly convex between right and left claspers (Fig. 4). It is desirable that the other species should be examined to determine whether the male genitalia and any other structures can be used as group characters.

In the *elegantulus* group are included *elegantulus* (Reuter, 1905) (Australia and New Zealand), *filicicola* (Kirkaldy, 1908) (Fiji and Samoa), *nigricornis* Poppius, 1912*a* (New Guinea), *jacobsoni* Poppius, 1914 (Java), *ochraceus* Usinger, 1946 (Guam), and *amboinae* n. sp. (Amboina, E. Indies). The features of this group are the cylindrical first antennal segment, not swollen subbasally, the distinctly excavated base of the pronotum, and the

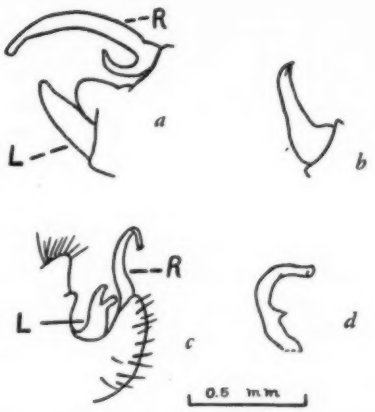

FIG. 4. Male genitalia, *magnificus* group (R, right clasper; L, left clasper). *Felisacus magnificus* Distant: *a*, Apex of abdomen (posteroventral); *b*, left clasper (posterior). *Felisacus philippinensis* Hsiao: *c*, Apex of abdomen (posterolateral); *d*, right clasper (ventrolateral).

differentiation of the base of the head as a cylindrical collum sharply and completely constricted from a wider region just behind the eyes. In *elegantulus*, *filicicola*, *ochraceus*, and *amboinae*, at least, the right clasper of the male is considerably widened and flattened basally and narrowed and curved apically, the inner margin with a more or less pronounced subbasal expansion; the left clasper is strongly curved upward and inward, with its outer margin strongly convex; ventral margin of apex of abdomen widely convex between right and left claspers. (See Figs. 2, 5.)

It seems possible that some or all of the following species might form a third group: *glabratus* (Motschoulsky, 1863) (Ceylon, Java, Philippine Is.), *auritulus* Distant, 1913 (Seychelles), *carpenterae* Hsiao, 1944 (Singapore and Borneo), and perhaps also *madagascariensis* Poppius, 1912*b* (Madagascar). From the descriptions, these would seem to present a different combination of characters from that shown by either of the other two groups, but none of these species has been examined in the present study.

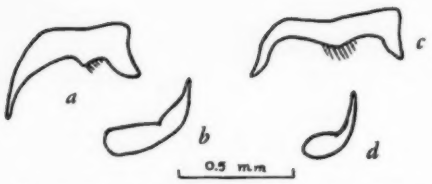

FIG. 5. Male claspers, *elegantulus* group. *Felisacus elegantulus* (Reuter): *a*, Right clasper (posteroventral); *b*, left clasper (lateral). *Felisacus ochraceus* Usinger: *c*, Right clasper (posteroventral); *d*, left clasper (lateral).

If critical study of a more complete series of species should uphold this or a similar division of the genus, it might be found advantageous to regard the groups as subgenera. In this case, provided *elegantulus* did not prove to fall into the same group as *glabratus*, *Hyaloscytus* Reuter, 1905, could be retained as a subgeneric name for the *elegantulus* group.

Each of the groups as tentatively designated above centres on a more or less distinct geographical range, with a number of aberrancies to be expected as the result of dispersal from the centre of origin. The first group is mainly northern Pacific, the second mainly southern Pacific, and the third more or less fringing the Indian Ocean.

It seems to the author not unlikely that some of the described species of *Felisacus* might eventually have to be considered as subspecies. For example, *filicicola* is very close to *elegantulus* and might have developed as a geographical race of the latter, whereas *usingeri* is close to *philippinensis*, and the former might perhaps prove to be a lowland race and the latter a high-altitude race of the one bitypic species. However, at present there are no criteria by which specific and subspecific limits in this genus might be satisfactorily demonstrated; until more complete evidence is available on extent of variation, distribution, biology, and interbreeding, and the structure of the male genitalia, it seems desirable to maintain specific status for all forms which are readily distinguishable on the basis of correlated structural differences.

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Three Pacific Species of "Lar" (Including a New Species), Their Hosts, Medusae, and Relationships. (Coelenterata, Hydrozoa)[1]

CADET HAND[2]

THE HYDROID "LAR," which lives as a commensal upon the tubes of sabellid polychaetes, has been described from the Atlantic by Gosse (1857) and from the Pacific by Uchida and Okuda (1941) and by Hand and Hendrickson (1950). Hincks (1872) noted that the medusae produced by *Lar sabellarum* Gosse were similar to *Willia stellata* Forbes, and later Browne (1896) clearly established that the medusa of *Lar sabellarum* was *Willia stellata*. Uchida and Okuda (1941), in their study of the Japanese "Lar," showed that their hydroid was that of the medusa *Proboscidactyla flavicirrata* Brandt and, as a result of their study together with the data of Browne and Kramp (1939), united the genera *Willia* and *Proboscidactyla*, retaining the name *Proboscidactyla* because of priority. Hand and Hendrickson (1950) described a new "Lar," *Proboscidactyla* sp., from California and suggested it might be the hydroid of the medusa *Proboscidactyla occidentalis* (Fewkes). Since 1950 the author has had an opportunity to examine medusae of *Proboscidactyla* from off the coast of Oregon, Monterey Bay, near Santa Cruz Island, and the San Diego region, the latter three localities all being in California waters. It also has been possible to obtain specimens of "Lar" from Puget Sound (Washington) and La Jolla, California. An examination of the hydroids and medusae has shown that three separate species of *Proboscidactyla* occur on the Pacific coast of the United States, a northern species (*P. flavicirrata*), a central species (*Proboscidactyla* sp. of Hand and Hendrickson 1950, named for the first time in the present report), and a southern species, *P. occidentalis*.

The definition of species in the Hydrozoa, more especially among the gymnoblasts, has long been based on rather gross, frequently ephemeral, characters such as size, shape, number and type of tentacles, arrangement of hydrorhizae, and the kinds of individuals present in the colony. In the following report, a not completely proved hypothesis has been used as one of the primary criteria of what is to be taken as a species. This concerns the nematocysts, and, briefly stated, the hypothesis is that each species of coelenterate can be identified by its possession of a unique group of nematocysts (the cnidom), at least with regard to size and shape, although not necessarily with regard to kind. This hypothesis has stemmed from the work of Weill (1934) and has proved acceptable for sea anemones as demonstrated by the numerous studies of Dr. Carlgren of Lund, Sweden. The work of E. G. Papenfuss (1936) on scyphomedusae and of F. S. Russell (1938) on hydromedusae lends much validity to the contention. To date no refutation of this hypothesis has been presented, and the study of the species of "Lar" demonstrates the further usefulness of nematocysts in the identification of hydroids. The terminology of nematocysts used herein is that of Weill (1934).

It will be noted in the following pages that the nematocysts of the hydroid stages are very similar from species to species. This, perhaps, is not unexpected as hydroids are immature

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organisms and would be expected to resemble one another more closely than the adults of different species. However, when we add the small differences in size and shape of nematocysts to the morphological differences of the hydroid stages, we find that these animals can be readily identified as separate species. The nematocysts of the medusae of these species, on the other hand, show greater differences, and again we would expect this, from the thesis that adults of related animals are less alike than their younger stages. It is, however, somewhat disappointing to discover that the medusoid and hydroid stages of a genus do not possess the same cnidom. Thus, in *Proboscidactyla* we find that the hydroids may be characterized as possessing a cnidom of three types of nematocysts (macrobasic euryteles, microbasic euryteles, and desmonemes), whereas the medusan cnidom consists of but two types (macrobasic euryteles and desmonemes). This should serve as a warning that hydroids and their medusae may not be identifiable with one another on a basis of their nematocysts. Moreover, this divergence of cnidoms in the two phases of the life history seems to imply that the nematocysts are adaptive characters which respond to environmental demands, and perhaps we should advance with caution along the road of relating larger groups such as genera and families on a basis of their nematocysts.

In the following discussion, in order to speak clearly of the arrangement of the tentacles and canals of the medusae of *Proboscidactyla*, a convention has been adopted in which the first four tentacles to develop are called *first order tentacles* and their canals are the *first order canals*. The second four tentacles arise to the right of the first order tentacles and are called *second order tentacles*. These tentacles arise at the margin of the bell at the point at which the *second order canals* join the ring canal. The *third order tentacles* are the the next eight tentacles which arise at the ends of the branches from the first and second order canals. Beyond the third order the arrangement of tentacles and canals is more difficult to discern. On specimens with 32 tentacles a rather clear *fourth order* of tentacles and canals can usually be made out, but on specimens with more than 32 tentacles the arrangement seems to have lost the regularity presented by the younger medusae. It has been noticed that, after the first order canal gives rise to the second order branch on its right and the third order branch on its left, it usually does not branch again and that most later branches arise from either the second and third order canals or from the rather diffuse fourth order.

The following material, upon which part of the descriptions presented herein are based, has been deposited in the U. S. National Museum.

1. *Proboscidactyla flavicirrata*, adult medusae, 20 specimens, U.S.N.M. 50035.
2. *P. flavicirrata*, hydroids on tubes of *Schizobranchia* and *Pseudopotamilla*, 6 specimens, U.S.N.M. 50036.
3. *P. flavicirrata*, hydroid on *Schizobranchia*, 1 specimen, U.S.N.M. 50037.
4. *Proboscidactyla circumsabella*, HOLOTYPE, adult medusa, 1 specimen, U.S.N.M. 50038.
5. *P. circumsabella*, paratypes, medusae, 8 specimens, U.S.N.M. 50039.
6. *P. circumsabella*, hydroids on *Pseudopotamilla*, 11 specimens, U.S.N.M. 50040.
7. *Proboscidactyla occidentalis*, medusae, 12 specimens, U.S.N.M. 50041.
8. *P. occidentalis*, hydroid on *Pseudopotamilla*, 1 specimen, U.S.N.M. 50042.

Proboscidactyla flavicirrata Brandt

THE MEDUSA: This medusa was first described by Brandt (1834) from the north Pacific and has subsequently been found near Japan and as far south as Puget Sound on the American side of the Pacific. Twenty-eight specimens of this medusa taken during August, 1949, have been found in plankton samples collected in the area from the mouth of the Columbia River on the north to Cape

Blanco, Oregon, on the south and at a distance of from 40 to 200 miles from shore. This plankton was collected by the Scripps Institution of Oceanography as part of its work on the California Cooperative Sardine Research Program. All the specimens observed possessed four first order radial canals and were in adult or nearly adult condition. The diameter of the bell varied from 6 to 10 millimeters and the height from 6 to 8 millimeters. They possessed from 40 to 72 tentacles.

The branching of the radial canals is very complex and highly irregular although the number of terminal branches in each quadrant is nearly equal on any given specimen. Thus, on a specimen possessing 72 tentacles, the quadrants had 17, 18, 18, and 19 tentacles, respectively. This condition is illustrated by Figure 1*g–j*. It will be noted that a canal branch does not run to each tentacle. In most specimens it appeared that the tentacles were more numerous than the canals, which condition may or may not actually exist, as the specimens examined were badly contracted and it was difficult to determine the distribution of the radial canals. In one specimen an anomalous condition was found in which the canals from two adjacent quadrants had anastomosed (Fig. 1*k*).

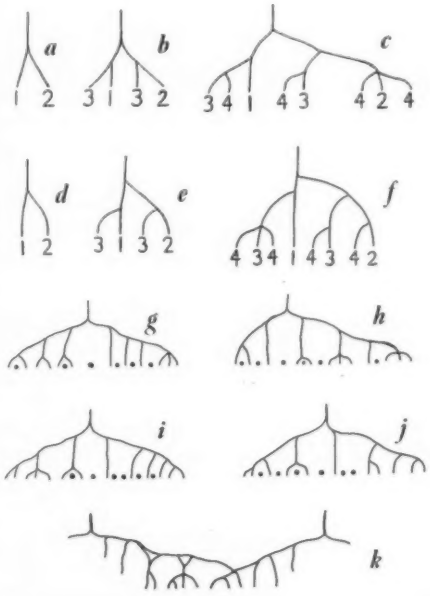

FIG. 1. *a–c, Proboscidactyla occidentalis; d–f, P. circumsabella;* and *g–k, P. flavicirrata*, showing (diagrammatically) the branching of the radial canals. The numbers in figures *a* to *f* refer to the order of the canals and tentacles. The spots between the ends of the canal branches in figures *g* to *j* represent the position of tentacles to which no canals could be seen to be branching.

Cnidothylacies (nematocyst sacs) are present on the exumbrellar surface and are connected to the solid ring canal by a chord of what are presumed to be endodermal cells. In many specimens no ring canal can be found, and here the chord of cells merely ends where the canal used to be. Uchida and Okuda (1941) noted that the ring canal of this species degenerates as the medusa matures, whereas Browne (1906) suggested that the disappearance of the ring canal was not unexpected, as each tentacle is directly connected to the stomach via the system of branched canals. The cnidothylacies never occur in association with the first order tentacles but can be found above all other tentacles and in the intertentacular spaces. Most specimens, however, show a somewhat irregular distribution of these structures, and the greatest number observed in any one quadrant was 14.

When this medusa is adult the gonads appear as white to creamy (formalin-preserved color) folded masses covering most of the stomach. The four gonadial masses present occupy interradial positions, each mass being developed as a pair of thickened lobes upon the adradial sides of the quadratic stomach with a thin sheet of gonadial tissue connecting the two lobes and covering the stomach wall. The gonads do not appear to fuse across the radial margins of the stomach. The lips of the manubrium are highly folded and hang but a short distance below the oral end of the gonads. Figure 2 illustrates the several features just mentioned.

The tentacles, which are inserted into the bell margin by endodermal bulbs, were quite contracted in most specimens; however, it was immediately apparent that the older tentacles are somewhat longer and larger than the younger ones. The tentacle bulbs are light yellow to cream in color and much more opaque than the tentacles.

The shape and general appearance of the medusa is shown in Figure 2, although only one quadrant is shown with all its details. It will be noted that there are four interradial, subumbrellar pouches which extend the subumbrellar cavity well above the level of the stomach. This is a characteristic of all three of the species described in this paper.

The nematocysts of the genus *Proboscidactyla* are known for the hydroid in two instances (Russell, 1938; Hand and Hendrickson, 1950) and in one case for the medusa (Hand and Hendrickson, 1950) and in this latter case only for very immature medusae. The nematocysts of adult *P. flavicirrata* were studied, and a simple cnidom of two types was found as follows:

Cnidothylacies
Macrobasic euryteles... 22—30×9—14μ
Desmonemes..... 5— 7×4— 6μ

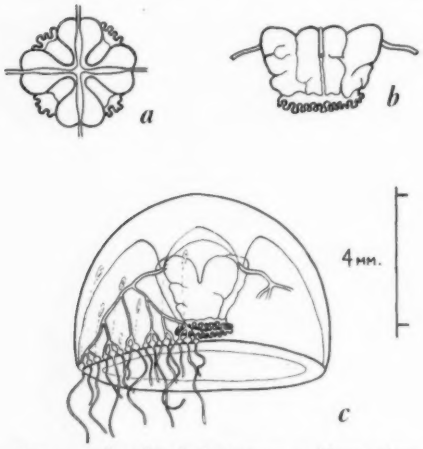

FIG. 2. *Proboscidactyla flavicirrata*. *a*, Aboral view of the stomach; *b*, side view of stomach; *c*, whole medusa with only one quadrant shown in detail.

Tentacles
Macrobasic euryteles... 8—12×5— 7μ
Desmonemes..... 5— 7×4— 6μ

Figure 3*a–c* illustrates the nematocysts. The desmoneme of the cnidothylacies appears to be identical to that of the tentacles.

THE HYDROID: Uchida and Okuda (1941) have given a rather complete description of this hydroid, although a few additional remarks and comparisons of their report with material from Puget Sound seems desirable. Several colonies of this hydroid were collected during the summer of 1950 in Puget Sound by Dr. Ralph I. Smith of the University of California at Berkeley and were given to the author for study. Detailed notes and sketches of the appearance and color of this hydroid in life were also gratefully received from Dr. Smith.

The organization and arrangement of individuals in *P. flavicirrata* are quite different from those of the other Pacific species. The gastrozooids and gonozooids stand in a double row or ring around the lips of sabellid tubes with the gastrozooids innermost, while the naked hydrorhizae tend to form parallel rows extending several millimeters along the long axis of the worm tube with occasional random anastomoses. The gonophores may arise either from the hydrorhiza near the base of an adjacent gastrozooid or actually from the proximal portion of the gastrozooid (Fig. 4*b*, *c*). What are presumed to be young or abortive gonozooids may occasionally be found at almost any point among the hydrorhizae, although they were not as numerous as those found by Uchida and Okuda. Where young or new gonozooids are forming on the bases of the gastrozooids, the appearance is that the gastrozooid is growing a tail (Fig. 4*a*). Figure 4*b* illustrates the general appearance and organization of a colony.

A total of 16 colonies was observed, and of these seven showed strongly parallel hydrorhizal nets and the remaining nine varied from a reasonably close approach to parallel

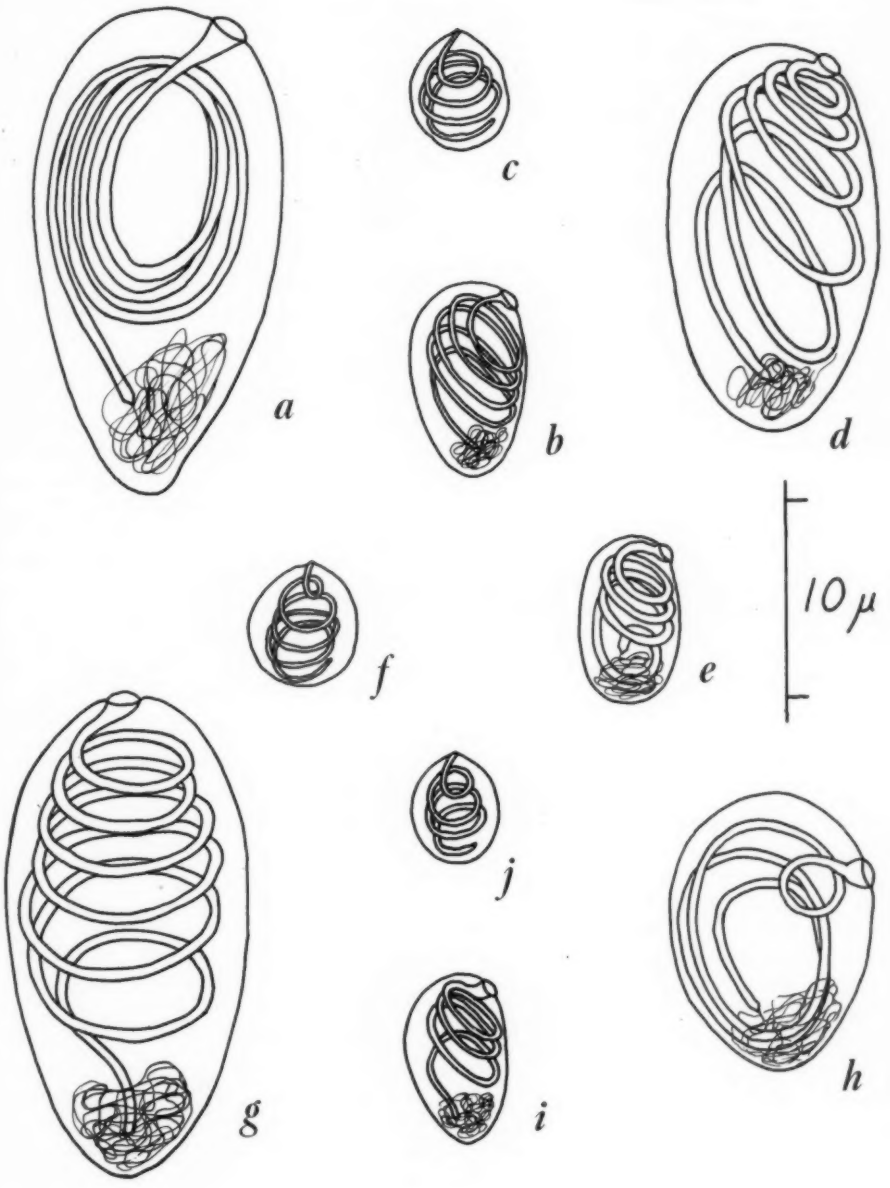

FIG. 3. The nematocysts of the medusae. *a–c, Proboscidactyla flavicirrata; d–f, P. circumsabella; g–j, P. occidentalis. a, b, d, e, g, h, i* are macrobasic euryteles; *c, f, j* are desmonemes.

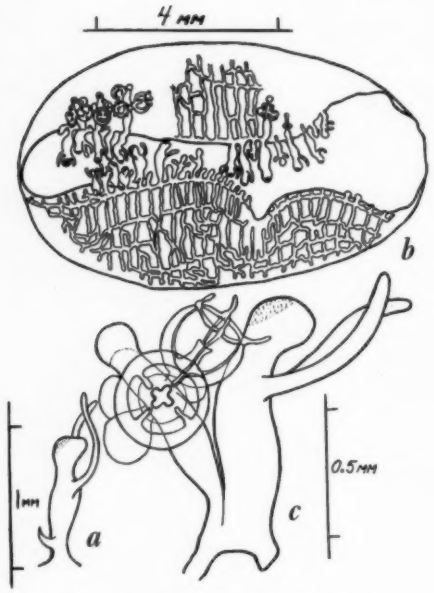

FIG. 4. The hydroid of *Proboscidactyla flavicirrata*. *a*, Young gastrozooid with a "tail"; *b*, a colony, only part of which is shown, as seen by looking down upon the end of a worm tube; *c*, gastrozooid and gonozooid, the latter with several medusa buds.

networks to very random, irregular networks. It was noted that the nine colonies showing the less parallel hydrorhizal networks also possessed very slightly smaller gastrozooids than the other seven colonies and that these nine colonies were the only ones possessing scattered gonozooids or no gonozooids at all. Some of these colonies were obviously immature, whereas others were quite mature. It was thought that these nine colonies might be of some other species, but this idea was discarded as no differences between these and the larger colonies could be found in their nematocysts. So far no one has demonstrated whether a single colony of "Lar" produces only one sex of medusa or whether both sexes can be produced by a single colony, so the suggestion may be tentatively put forth that the visible morphological differences in the Puget Sound "Lar" may be of a sexual nature.

The color of this hydroid in life is, in general, orange to pink with the color restricted to the endoderm as in other species. The gastrozooids are 0.8–1.2 millimeters tall by about 0.2 millimeter in diameter. The gonozooids are in general thinner and slightly shorter than the gastrozooids. Two tentacles are present on the gastrozooid and none on the gonozooid. The size of the Puget Sound individuals is slightly larger than that of those from Japan, and no variation in tentacle number was noted, whereas a number of specimens with extra tentacles was reported from Japan. The Puget Sound "Lar" possessed from two to eight medusa buds, commonly eight, with four of the buds large and well developed and four as small, poorly developed medusae. The four small buds alternate with the four large ones, and all buds seem to arise at a single level slightly above the middle of the gonozooid.

The nematocysts of the hydroid are as follows:

Macrobasic euryteles	17—25×8—12μ
Large microbasic euryteles	10—18×4— 6μ
Small microbasic euryteles	5— 6×2— 3μ
Desmonemes	3— 5×2— 4μ

The tentacles of the polyps seem to possess only the small microbasic euryteles listed above, whereas the three remaining types were found in the caps of the polyps. The desmoneme and the large microbasic eurytele also occur in small numbers over the surfaces of the polyps. Figure 5*a–d* illustrates the appearance of the nematocysts of this hydroid.

THE HOSTS: Uchida and Okuda (1941) reported this species upon the sabellid, *Potamilla myriops*. Berkeley and Berkeley (1952) do not list this species for the Puget Sound area but do list *Potamilla neglecta*, which is one of the hosts for *Proboscidactyla occidentalis*, the third species of this report. *Proboscidactyla flavicirrata* occurred on two species of sabellids in the Puget Sound area, namely *Schizobranchia insignis* and *Pseudopotamilla ocellata*. Ten genera of sabellids were reported by

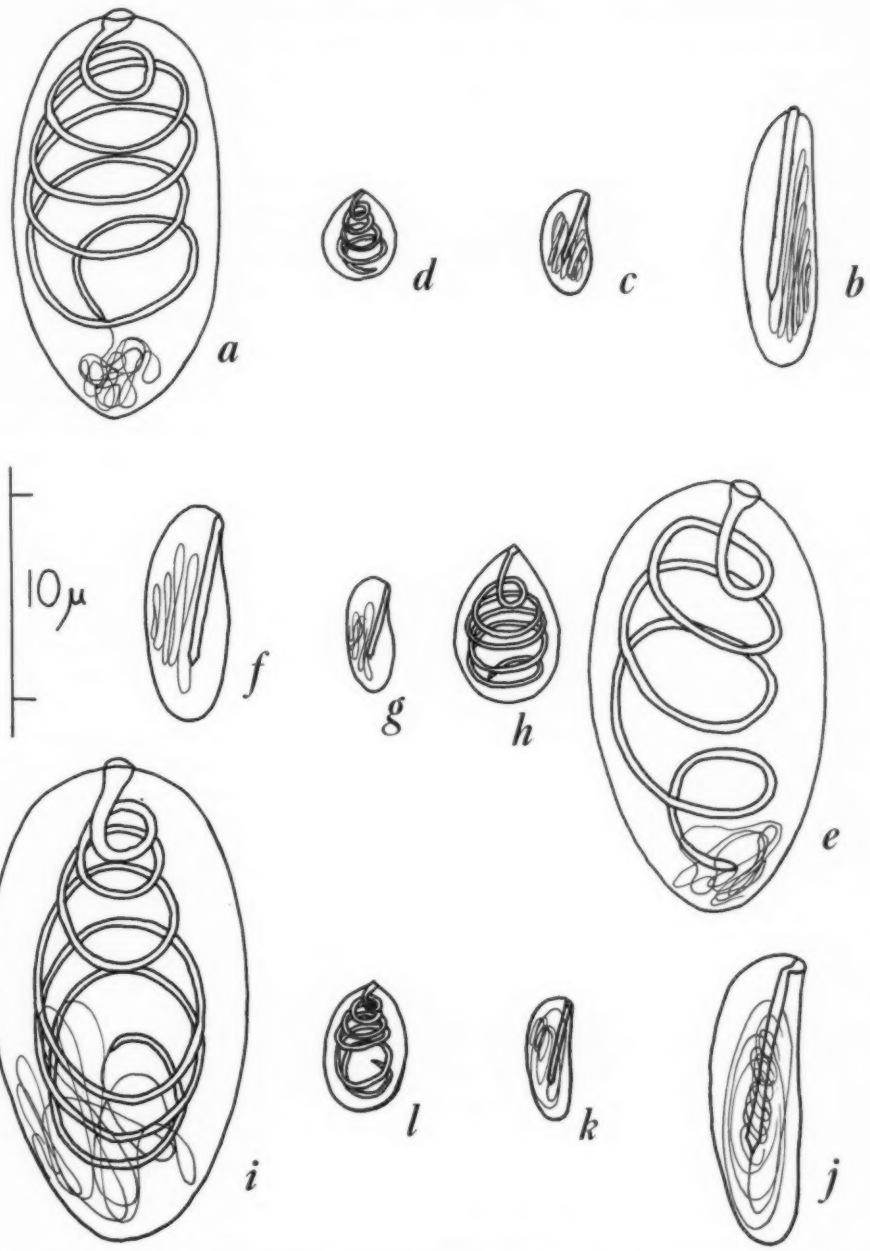

FIG. 5. The nematocysts of the hydroids. *a–d, Proboscidactyla flavicirrata; e–h, P. circumsabella; i–l, P. occidentalis. a, e, i* are macrobasic euryteles; *b, c, f, g, j, k* are microbasic euryteles; *d, h, l* are desmonemes.

Berkeley and Berkeley (1952) from the Pacific area around Puget Sound, with a total of 19 species involved. It seems likely that further observation will reveal the presence of this hydroid upon still more sabellids than the three from which it has been reported to date.

The observed difference in size of individuals and in colony morphology reported in the description of this hydroid does not seem to be correlated with the host upon which the colony is growing. Colonies with both parallel and irregular hydrorhizal nets were found upon both of the sabellids reported above as hosts for *Proboscidactyla flavicirrata* in the Puget Sound area.

Proboscidactyla circumsabella sp. nov.

The hydroid and young medusa of this species were first described by Hand and Hendrickson (1950) under the name of *Proboscidactyla* sp. Since that description appeared, a series of medusae of this species ranging from small immature specimens to adults have been obtained from plankton from Monterey Bay. I am indebted to Mr. Frank Gwilliam and Mr. Meridith Jones of the University of California at Berkeley for some of these specimens.

As the hydroid and young medusa have already been described, it does not seem necessary to repeat the whole diagnosis at this time, but certain salient features are worth repeating for the sake of comparison with the other two species considered here.

THE MEDUSA: Adult medusae were collected during the months of June and July, 1951, and a single specimen during July, 1952. A total of nine adult medusae have been examined.

The largest specimen observed measured 3.0 millimeters, bell diameter, by 2.5 millimeters high. This specimen possessed 32 tentacles and 28 cnidothylacies. The gonads were well developed and occurred in the interradial position as four paired masses of simple swollen lobes on the adradial sides of the stomach. Figure 6*a–c* illustrates the appearance of a living, 24-tentacled, adult medusa as well as the details of the shape and location of the gonads and the lips of the manubrium. The manner in which the lips fold seems to be characteristic of this species.

From a study of the nine medusae in hand, it appears that a rather regular system of branching of the radial canals obtains in this species, with the result that the adult medusae are quite uniform. Of the specimens examined only a single one deviated from the pattern of development presented in Figure 1*d–f*. This single specimen possessed 25 tentacles, the single unusually located tentacle occurring to the right of the second order tentacle of one quadrant and connected to the second order canal by a short canal of its own. In immature or developing medusae there is an obvious difference in tentacle length, tentacle bulb diameter, and radial canal size; the older tentacles, tentacle bulbs, and radial canals are longer or larger, and thus the developing complexity of the canal system is readily visible. From the time the medusae reach the 16-tentacle stage until they attain the 32-tentacle condition the exact order of appearance is not precise; therefore, specimens may have odd numbers of tentacles, although the end result is uniform as judged by the four specimens which possessed 32 tentacles.

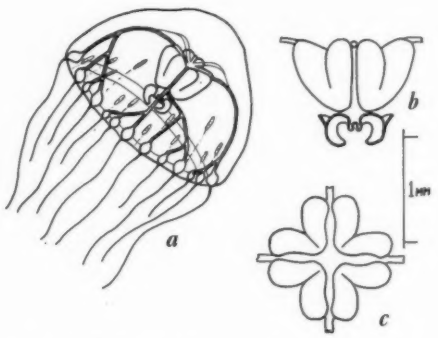

FIG. 6. *Proboscidactyla circumsabella*. *a*, Whole medusa, with tentacles shown on one half only; *b*, side view of stomach; *c*, aboral view of stomach.

In life this medusa is nearly colorless, pigment being restricted to the tentacle bulbs and the wall of the stomach. These areas are brown to orange brown. The tentacle bulbs appear to develop before pigment is deposited in them so that the small tentacle bulbs are colorless or nearly so. The older tentacle bulbs are usually a bright orange-brown color. The gonads are very lightly colored, those of the males being white and of the females a light creamy color. The sexes are separate.

The nematocysts of adult *P. circumsabella* are as follows:

Large macrobasic euryteles	17—26×8—12μ
Small macrobasic euryteles	7—10×4— 5μ
Desmonemes	5— 7×4— 6μ

The large macrobasic euryteles are restricted to the cnidothylacies, whereas the small macrobasic euryteles occur in the tentacles. The desmonemes are present in both the tentacles and cnidothylacies. The large macrobasic euryteles occur in very small numbers, and not all cnidothylacies were found to possess them (Fig. 3*d–f*).

THE HYDROID: The hydroid is similar to other species of *Proboscidactyla* in that the colony possesses two major types of individuals, the two-tentacled gastrozooids and the gonozooids, which are without tentacles and bear the medusa buds. Small gonozooids or dactylozooids occur at the margins of the hydrorhizal network. The gonozooids occur as scattered individuals arising from the hydrorhizae and are never arranged in a row immediately behind or on the gastrozooids, as in *P. flavicirrata* or *P. stellata*. Up to a maximum of four medusa buds may be borne upon a single gonozooid. The individuals of a colony seldom are as much as 1 millimeter tall and are commonly about 0.8 millimeter tall by about 0.1 millimeter in diameter. The hydrorhizal network is devoid of any covering and may form extensive anastomosing nets running along the tube for as much as 15 millimeters.

The nematocysts of the hydroid are as follows:

Macrobasic euryteles	16—24×9—12μ
Large microbasic euryteles	9—12×3— 4μ
Small microbasic euryteles	5— 6×2— 3μ
Desmonemes	6— 8×3— 4μ

The macrobasic euryteles occur only in the cap of the gastrozooid and the tip of the gonozooid. The other three types of nematocysts occur in most areas of the gastrozooid and gonozooid although no small microbasic euryteles were found in the gonozooids. Figure 5*e–h* illustrates the nematocysts of the hydroid.

THE HOSTS: *Proboscidactyla circumsabella* occurs most commonly on the sabellid *Pseudopotamilla ocellata*. Careful observation of other sabellids, such as *Eudistylia polymorpha* and *Sabella media* which sometimes occur with *Pseudopotamilla ocellata*, have failed to reveal the presence of a single "Lar" on the tubes of these other worms. This may be due to the fact that these worms commonly grow to a considerably larger size than the common host and are for this reason an unsuitable substrate. Other sabellids, such as *Myxicola* and *Eudistylia vancouveri*, have tubes whose consistency or structure make it impossible for this hydroid to live upon them. Of the several different sabellids examined from Monterey Bay and vicinity only a single example of "Lar" upon any host other than *Pseudopotamilla ocellata* has been found, and this was a small colony on the tube of *Pseudopotamilla intermedia*. This worm had built its tube of elongate, rather pointed, sand grains and presented a much more irregular substrate to the hydroid than the tubes of its regular host. It appears that *Proboscidactyla circumsabella* is limited to hosts whose tubes do not reach very large sizes, whereas *P. flavicirrata* may be found upon tubes up to about 1 centimeter in diameter. The largest worm tube upon which *P. circumsabella* has been found was about 4 millimeters in diameter.

Proboscidactyla occidentalis (Fewkes)

In 1889, Fewkes described a medusa, *Willia occidentalis*, from near Santa Cruz Island. From his description it is clear that this medusa is a *Proboscidactyla*, and, moreover, it is presumed that this species is identical to that found at La Jolla, California, because a single specimen collected in 1950 near Santa Cruz Island is identical to the more abundant La Jolla material. Thirty-one medusae with 8–40 tentacles have been examined from the San Diego area, as well as a single 28-tentacle specimen from Santa Cruz Island plus 18 colonies of a hydroid which have been assigned to this species. The hydroids were found on sabellid tubes which were associated with a kelp holdfast. This kelp holdfast was growing in 40 to 50 feet of water and was obtained by Conrad Limbaugh on April 12, 1952, while diving with an aqua-lung at La Jolla. The samples from which the medusae were obtained were collected by Conrad Limbaugh, Robert Bieri, and John Bradshaw, of the Scripps Institution of Oceanography.

THE MEDUSA: Medusae of this species have been found in plankton samples collected at Santa Cruz Island in the month of March, 1949, and from La Jolla and San Diego Bay during the months of March through July, 1952. The largest medusa collected was a female 3.5 millimeters high by 3.5 millimeters in diameter. This medusa possessed 40 well-developed tentacles. The smallest medusa was slightly greater than 1 millimeter in height and diameter and possessed eight tentacles. In life little pigment is to be seen on these medusae, except for the dark reddish-brown to black bulbs of the tentacles. Some specimens show a little light-brown pigment in the stomach walls.

The gonads are apparent on 8-tentacled medusae but do not begin to bulge from the adradial walls of the stomach until about the 16-tentacle stage. The gonads appear ripe at the 32-tentacle stage, and the female possessing 40 tentacles seemed to have shed part of the eggs from one quadrant of the gonads. As in the other species of *Proboscidactyla*, the gonads do not fuse across the radial margins of the stomach and are disposed as four interradial masses consisting of paired adradial lobes connected at the interradii by thin sheets of gonadial tissue. The gonads, when fully ripe, show folds along their medial surfaces. The sexes are separate.

The manubrium is very short and the lips are highly folded. This species closely resembles *P. flavicirrata* in this respect.

The radial canals branch, and the general pattern and order of development is presented in Figure 1*a–c*. Small variations in the location and length of the branched canals occur from quadrant to quadrant and specimen to specimen; however, the order and final arrangement seems to be relatively definite so that when the 32-tentacle stage has been reached a difference in pattern of branching is apparent when it is compared with the same stage of *P. circumsabella*. This difference consists of a pair of fourth order tentacles spanning the second order tentacle in *P. occidentalis*, whereas in *P. circumsabella* a pair of fourth order tentacles span the left hand third order tentacles (compare Fig. 1*c* and 1*f*).

In the figure of this species in Fewkes (1889) a 20-tentacle medusa is shown. This is presumably a fleeting stage in development in which the first of the fourth order tentacles had appeared. The radial canals shown in Fewke's figure represent a condition seldom attained in this species in that he has shown the canal branched into three equal parts, with each of the lateral branches possessing another branch. The manner in which the canals of all species of *Proboscidactyla* branch is such that this is nearly an impossibility. It is presumed that Fewkes drew a symmetrical diagram which was not a copy of the actual pattern present. It will be noticed, if one compares the figures of the three species of this report showing the systems of branching canals, that *P. occidentalis* and *P. flavicirrata* tend to present a pattern in which the primary

radial canal of each quadrant bifurcates rather symmetrically, whereas in *P. circumsabella* the primary canal seems to run directly to the margin, giving off its branches laterally. This difference is not absolute but applies in most specimens.

A ring canal was present in most of the individuals observed, although the specimens possessing 32 or more tentacles did not show this structure. The disappearance of the ring canal seems to be a characteristic of adulthood of this genus.

The bell of this species is somewhat thicker then that of the other two species, and, also, the tencency for the height to be the same as, or greater than, the diameter is striking. In preserved specimens the adoral end of the stomach never is located more than half the distance from the velar opening to the adoral tip of the bell (see Fig. 7). Fewkes (1889) described a slight constriction in the external outline of the bell at a level with the base of the stomach and showed this constriction in his figure. This constriction was apparent in two of the 31 specimens examined but apparently is not characteristic of the species.

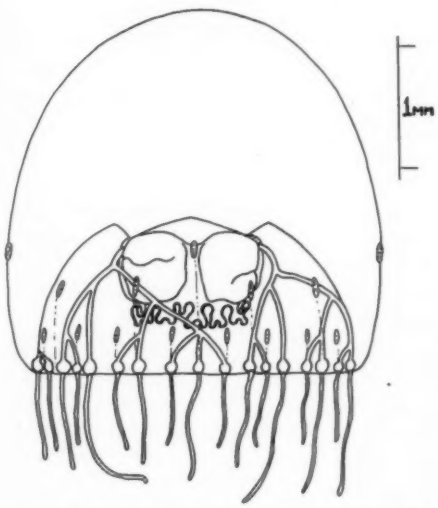

FIG. 7. *Proboscidactyla occidentalis*. Whole medusa with tentacles shown on one half only.

More commonly the bell is hemispherical or is of an elongate shape such as could be depicted by a figure representing slightly more than half of an oval.

The nematocysts of the medusa present a familiar pattern. Only two kinds, macrobasic eurytheles and desmonemes, are present, but a rather unusually shaped medium-size macrobasic eurytele occurs in the cnidothylacies. This nematocyst (Fig. 3*h*) is distinctive of this species. In the tentacles a more usual, small, macrobasic eurytele is numerous, as are desmonemes. The nematocysts of this species were found to be as follows:

Cnidothylacies	
Large macrobasic eurytheles	24—28×11—14μ
Medium macrobasic eurytheles	12—17× 8—12μ
Desmonemes	5— 6× 4— 5μ
Tentacles	
Small macrobasic eurytheles	7—10× 4— 5μ
Desmonemes	5— 6× 4— 5μ

Figure 3*g–j* illustrates the nematocysts of this species.

THE HYDROID: The hydroid stage of this species resembles in its general form that of other known species, its most singular character being that the gonophores bear large numbers of medusa buds which were not discerned to have a regular arrangement upon the gonophores. A maximum of 12 buds was found to occur on a single gonophore among the colonies examined. This material was collected on April 12, 1952.

The gastrozooids are arranged around the lips of sabellid tubes, sometimes forming a complete circle, the two tentacles and mouth facing the orifice of the tube. One colony, which was growing on a tube which was damaged on one edge, was located about 1.5 millimeters inside the lip of the tube. Because of the manner in which the lip of the damaged tube flared out, this placed the colony in

direct contact with the bases of the worm's tentacles, which is the normal position, although its location inside the tube was unusual. The hydrorhizal net of this specimen started on the outside of the tube, traveled up the tube to its lip, and then down inside the tube to the ring of gastrozooids. The location of this colony suggests that the individuals may have migrated from the old lip to the new position, although it may be that the hydroid settled upon the tube after it had been damaged. It is not known how "Lar" responds as its host lengthens and enlarges its tube, if indeed the worm does so, after a colony has established itself upon it.

The individual gastrozooids are never more than 1 millimeter tall and are rather stout, being 0.2 to 0.3 millimeter thick. The nematocyst pad on the "head" is well developed and is devoid of pigment, as is the ectoderm in general. The endoderm is brown.

The gastrozooids are connected to one another via a network of anastomosing, naked hydrorhizae, these hydrorhizae not exceeding 0.1 millimeter in diameter.

Tentacleless gonozooids occur as scattered individuals arising from the hydrorhizal net. The gonozooids are about 1 millimeter tall and bear a capitate, mouthless tip which is studded with nematocysts. From 2 to 12 medusa buds are borne on each gonozooid. They arise at irregular intervals slightly above the mid-point. The medusa buds show four spots of brownish-red pigment which correspond to the developing first order tentacle bulbs and also a brownish pigment mass representing the developing stomach. Medusa buds were seen pulsating on several colonies, but none were released before the specimens were preserved.

The nematocysts of the hydroid were studied and found to be as follows:

Macrobasic euryteles	20—28×8—11μ
Large microbasic euryteles	12—24×4— 6μ
Small microbasic euryteles	5— 8×2— 3μ
Desmonemes	6— 9×3— 4μ

The tentacles seem to possess only the small microbasic euryteles, whereas the macrobasic euryteles and desmonemes occur only in the cap of the gastrozooid. The large microbasic euryteles occur on the body of the polyp as well as in the cap. The body of the polyp also has small microbasic euryteles. Figure 5*i–l* illustrates the above nematocysts.

THE HOSTS: This species (*P. occidentalis*) has been found on two species of sabellids, *Potamilla neglecta* and *Pseudopotamilla intermedia*. These worms were kindly identified by Dr. Olga Hartman of the Allan Hancock Foundation. Sabellids are not well represented in the intertidal region near La Jolla, and only a few small specimens of *Pseudopotamilla intermedia* have been collected. These did not have any "Lar" upon them. The material upon which the hydroid was found was taken from 40 to 50 feet of water, as mentioned earlier.

DISCUSSION

A group of organisms, such as is represented by the genus *Proboscidactyla*, presents a number of interesting problems to the biologist. One of these problems concerns the matter of symbiosis, more specifically commensalism in this instance, and a second concerns the special life history of this group with the unavoidable complications encountered where the two phases of the life history are adapted to, or are adapting to, very different environmental factors.

In the Hydrozoa the tentacles, with their associated nematocysts, represent the primary tools for protection and food gathering, and there are few hydrozoans which can be pointed to as possessing reduced numbers of tentacles. *Protohydra* and *Tetraplatia* are curious among the Hydrozoa, indeed among the Coelenterata, in that these free living animals possess no tentacles at all. On the other hand, among the symbiotic Hydrozoa a rather large group

of hydroids exists which possesses reduced numbers of tentacles, and some have none. Such forms as *Hydrichthys*, *Icthyocodium*, and *Nudiclava* are tentacleless, whereas *Monobrachium* has but one and *Proboscidactyla* but two tentacles. The possibility exists that the tentacleless forms exhibit a true parasitism in which the hydroid uses the hosts' tissues for its food, as was claimed for *Hydrichthys* by Warren (1916). The exact manner in which *Monobrachium* is adapted to its bivalved host is not clear inasmuch as living specimens have not been studied, but for at least two of the 2-tentacle *Proboscidactyla* we have adequate descriptions of tle living animal (Gosse, 1857; Hand and Hendrickson, 1950). From these descriptions we can see how well fitted these animals are for their special way of life, but they seem to have sacrificed certain usual hydroid traits and the versatility of substrate requirements of most hydroids for the limited substrate offered by certain sabellids. The known genera upon which these hydroids occur represent but a small number of those which appear to be available. Only *Potamilla*, *Pseudopotamilla*, and *Schizobranchia* have so far been reported as bearing *Proboscidactyla*. Studies concerning host choice and relationships among this group would appear to be worth pursuing.

In most respects the life history of *Proboscidactyla* differs but little from that presented in freshman biology as characteristic of the Hydrozoa. However, a life history such as this, with two well-developed, relatively long-lived phases, is rather unusual in the animal kingdom and presents certain difficulties to the student of the group. The hydroid phase is, in general, a sessile stage, adapted to its own environment, whereas the medusoid stage is pelagic and is adapted to a completely different mode of life. Most students of the Hydrozoa look upon the hydroid phase as a stage in development specialized for asexual propagation and upon the medusa as the adult, sexually reproducing stage of the life history. Because of this curious division of the life history, students of the Hydrozoa have developed two "schools," the one a group of specialists in hydroids, the other in hydromedusae. Therefore, we find today that in many instances there are two sets of nomenclature referrable to a given animal, and there is no immediate hope of reducing this gigantic taxonomic snarl to a satisfactory systematic treatment. The prime hope would seem to be the study of life histories in this group so that the medusae may be referred to their proper hydroids, and then gradually the two systems will become one.

In the nearly 100 years since Gosse (1857) described the first "Lar," only three additional species have been described. These three all occur along the Pacific coast of North America, with one of them ranging to Japan. The actual number of species which exist cannot be determined at this time, but the possibility that as many as a dozen occur is not improbable. Uchida and Okuda (1941) list four certain species of medusae of *Proboscidactyla* with a fifth, originally described by Uchida (1927) as *Misakia typica*, also included as a distinct species. The status of several of the ten species and varieties of *Proboscidactyla* and *Willia* of Mayer (1910) certainly remains in doubt, although the present study validates Fewkes' *Willia occidentalis* and adds a new species, *Proboscidactyla circumsabella*. Foerster (1923), in an excellent study of the hydromedusae of the west coast of North America and particularly of the Vancouver Island region, lists four species of *Proboscidactyla*. Of these, two are merely cited from the literature (*P. occidentalis* and *P. ornata* var. *stolonifera*), but the other two (*P. flavicirrata* and *P. polynema*) concern specimens taken in the Vancouver Island area. Foerster reported ocelli on the tentacle bulbs of *P. flavicirrata;* however, this statement and that of Uchida and Okuda (1941) are the only known instances where ocelli have been reported for proboscidactylans. In each instance, however, the report has concerned *P. flavicirrata*, so ocelli may occur in that species although specimens ex-

amined by the writer have not possessed ocelli. The species *Proboscidactyla polynema* of Foerster is referred to the animal described from the Atlantic by Hartlaub (1917) as *Pochella polynema*. This medusa has no cnidothylacies (centripetal canals of Foerster), and each primary radial canal gave off about six lateral branches on each side. These characters would make this an unusual species of *Proboscidactyla*, if, indeed, it is one at all.

The following four species of *Proboscidactyla* now have been described for both the hydroid and medusoid stage of the life history.

P. stellata (Forbes) (Hydroid *Lar sabellarum* Gosse)
P. flavicirrata Brandt
P. occidentalis (Fewkes)
P. circumsabella n. sp.

This leaves an ample number of hydroid stages to be described, such as the several which presumably live along the Atlantic coast of the United States. At least one of these hydroids is known to occur in Long Island Sound (E. S. Deevey, *in litt.*). This hydroid will probably be identified with the medusa *P. ornata* (McCrady) when a critical study is made.

In considering a group of species it is always interesting to see if a key to their evolution or the manner in which they are related can be found. A group such as *Proboscidactyla* has no fossil record to help us, and today they are widely distributed. At least four species occur in the Pacific and an equal number in the Atlantic. This does not immediately suggest a key to their evolution.

If the hydroid stages of *Proboscidactyla* are compared, certain relationships are suggested. *P. stellata* and *P. flavicirrata* both have gonophores borne close to or upon the gastrozooids, whereas neither of the other two species whose hydroids are known is so constructed. Also, *P. stellata* commonly produces six-rayed medusae, whereas *P. flavicirrata* may have four, five, six, or eight radial canals. This suggests a relationship between these two, as the other two species seldom if ever produce anything other than four-rayed medusae. The nematocysts of the polyp stages of *P. stellata* and *P. flavicirrata* also resemble each other very much, but they also closely resemble those of *P. circumsabella* and *P. occidentalis*.

The gonozooids of the four species do not give us much help beyond their location on the colony. In *P. stellata* four medusa buds are usually produced, whereas *P. flavicirrata* may have up to eight buds; *P. circumsabella* seems never to produce more than four, whereas *P. occidentalis* produces up to 12.

The adult medusae of *Proboscidactyla* seem to offer the best evidence to their paths of evolution. *P. stellata* and *P. flavicirrata* have already been mentioned as having six or a variable number of radial canals, respectively, and it should be mentioned that *P. mutabilis* of the South Atlantic is even more variable than these two species. Of the three species of the present report, the northern species (*P. flavicirrata*) is largest and has more tentacles than its two southern relatives.

The nematocysts of the medusae are known for only the three species reported herein. Of the three, *P. occidentalis* is the most distinctive in that three sizes of macrobasic euryteles are present of which one, the medium size, is very unusual in shape. *P. flavicirrata* and *P. circumsabella*, on the other hand, possess only two sizes of macrobasic euryteles. If the nematocysts of the medusae are used to indicate relationships, it appears that the latter two species are more closely related to each other than to *P. occidentalis*. In summary, then, it appears that *P. stellata* and *P. flavicirrata* are closely related, the latter being also near *P. circumsabella*. *P. occidentalis* is somewhat more distantly related to these others in both its morphology and its geographic location.

Another interesting medusa, *P. ornata* (McCrady) var. *stolonifera* Maas, has been reported from the Pacific at Acapulco harbor (Mexico) by Bigelow (1909) and from the Malay Ar-

chipelago by Maas (1905). This variety should be elevated to at least the rank of subspecies and will be so considered in this study. *P. ornata stolonifera* is a good-size medusa (about 5 mm. diameter) but has few tentacles as compared to other Pacific species, its maximum number being about 20. Also, it is distinctive from other Pacific species in its possession of medusa-bearing stolons. It appears that this subspecies has been derived from the Atlantic *P. ornata–P. ornata gemmifera* complex, *P. ornata* (McCrady) being known from southern New England to Beaufort, North Carolina, and *P. ornata* (McCrady) var. *gemmifera* Fewkes (see Mayer, 1910, for first usage of this combination) from North Carolina to the Bahamas. As in the instance of the variety *stolonifera*, this variety (*gemmifera*), will be considered a subspecies. The species *P. ornata* is distinguished from its subspecies, *P. ornata gemmifera*, by the habit of the latter of producing medusa-bearing stolons which arise from the radial corners of the stomach. Thus we have an interesting series of medusae, ranging from New England to the Bahamas, which, as southerly regions are reached, seem to develop the character of asexually producing medusae from the medusa stage, and this southern form has a close relative in the warm waters of the Pacific which has a similar characteristic. If one allows the speculation, it seems possible that the Pacific *P. ornata stolonifera* was separated from the Atlantic *P. ornata gemmifera* after a period of submergence and emergence of the Panamanian Isthmus. It would be of real interest to study the host substrates of the "*ornata* complex" to see if these worms are related in a manner similar to that of the medusae.

Kramp (1952) has reported *Proboscidactyla ornata* from the west coast of Chile. He had but a single 3-millimeter specimen at his disposal, and this specimen was not in good shape. The possibility that *P. ornata* exists along the coast of Chile will not be denied; however, it may well be that this particular specimen really represents a young specimen of *P. mutabilis* or an undescribed species. That Kramp's medusa was not a *P. ornata* seems even more likely if one considers the known distribution of this species and its subspecies in conjunction with the existing current systems (see, for example, Chart VII in Sverdrup, Johnson, and Fleming, 1946).

Uchida (1927) rather thoroughly surveyed the anthomedusan fauna of Japan and in this study listed five forms of what now make up part of the genus *Proboscidactyla*, but did not at that time recognize *P. flavicirrata* as occurring in that area. In a subsequent report Uchida and Okuda (1941) reported from Japan a hydroid and medusa they took to be that of *P. flavicirrata*, which I assume to be correct. The identification of *P. ornata* and *P. ornata gemmifera* in Japan (Uchida, 1927) presents a problem in distribution and systematics. The *P. ornata* may well be the young of *P. flavicirrata*, but the phenomenon of budding in the medusoid stage has not been reported for this latter species, so that there is no ready suggestion as to what this budding form may have been. That *P. ornata* and some of its subspecies do or do not occur in Japan cannot be stated with certainty at this time. Moreover, the answer to this riddle may lie in the fact that the ability of medusae of this group to reproduce asexually may be more widespread than is now realized. A number of possibilities as to the identity of Uchida's *P. ornata* and *P. ornata gemmifera* certainly exist. The species *Willia stellata*, *Willia pacifica*, and *Misakia typica* of Uchida (1927) would best seem to be considered as synonyms of *P. flavicirrata*, although the critical test of this statement must await a study of their nematocysts.

In the many records of the occurrence of *Proboscidactyla*, one notable fact is that these medusae are absent from the high seas. They occur instead in bays and along the coasts of most parts of the world. This distribution must certainly be the result of the dependence of the hydroid upon sabellids, which worms are most common in shallow water. A second

curious phenomenon concerning the distribution of *Proboscidactyla* is the extremely wide range of the species, *P. ornata*. Kramp (1952) lists this species from the Pacific coast of Mexico, Japan, the tropical Pacific, the Malayan Archipelago, and from Madras, India, and, further, from the Atlantic coast of North America, the Bahamas, Brazil, and Fernando Po on the west coast of Africa. The other species have much more localized distributions. Maas (1905) has pointed out that the habit of budding practically puts *Proboscidactyla* in a class with holoplanktonic organisms. Actually, the habit of budding does not seem to be a character of the genus but rather of the subspecies of *P. ornata* which, indeed, may well account for its curious and widespread distribution.

At this time it would appear that the following species exist, occupying in general the following areas. Most of the literature relevant to these distributions has already been cited, and that which has been omitted can be found in Mayer (1910) or Browne and Kramp (1939).

1. *P. flavicirrata*	North Pacific
2. *P. circumsabella*	Central Californian Pacific
3. *P. occidentalis*	Southern Californian Pacific
4. *P. stellata*	European North Atlantic
5. *P. ornata ornata*	Atlantic, New England to North Carolina
6. *P. ornata gemmifera*	East and West Tropical Atlantic
7. *P. ornata stolonifera*	East and West Tropical Pacific to Indian Ocean
8. *P. mutabilis*	South Atlantic and Straits of Magellan

The above species may be related and may have evolved along the following lines, but, of course, this is speculative. To begin with, I suggest a northern, inherently variable medusa such as *P. flavicirrata* which possibly as a circumpolar species gave rise to the Atlantic *P. stellata*. *P. flavicirrata* or its predecessor also gave rise to *P. circumsabella* and to *P. ornata*. *P. ornata* seems to have developed its southern subspecies *gemmifera* in the Atlantic which by spanning the Panamanian Isthmus has given rise to the subspecies *stolonifera* which has spread via the tropical current systems throughout the tropical Pacific. *P. occidentalis* may be the offshoot of *P. ornata stolonifera* or of *P. circumsabella* or some other species. The origin of *P. mutabilis* of the Falkland Islands and perhaps of the Pacific is not apparent. However, another pattern of evolution can be suggested which, based upon major existing ocean currents, seems even more plausible. Thus, starting with the variable *P. mutabilis* and utilizing the currents of the South Atlantic Ocean, medusae could be carried to the Isthmus of Panama, to the Gulf Stream, and into the North Atlantic to England. The Pacific species could be derived from a crossing at Panama or by moving directly into the Pacific from the circumpolar Antarctic currents. It would be possible to start at almost any point in the oceans and arrive at the same end results.

It is, of course, not necessary to accept any point or species as the origin of this group of medusae; the important fact would seem to be that today *Proboscidactyla* is a genus which occurs in most oceans and presumably has spread to these oceans via ocean currents acting upon the planktonic medusoid phase of its life history. One factor which would appear to limit the distribution of this genus in its spread would be a lack of suitable hosts. Therefore, if this group and its evolution are to be understood adequately, further studies are needed not only on the hydroids and medusae but also on the sabellids to whose fate *Proboscidactyla* has apparently attached its own hopes for the future.

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Fishes Killed by the 1950 Eruption of Mauna Loa
II. Brotulidae[1]

WILLIAM A. GOSLINE[2]

DEEP-WATER BROTULIDS have not hitherto been recorded from Hawaii, or, for that matter, from the Central Pacific Ocean. The Mauna Loa collections contain five brotulid species belonging to four genera. None of the species can be allocated to known forms with any certainty, and three of them are described as new. One of the genera appears to be new.

Unfortunately, as is true of many deep-water collections, each of the species is represented by a single specimen. This restricts the possible value of the present report in two ways. In the first place, the type and range of variation within these Hawaiian species must remain for the present unknown, and the possibility exists that the specific and generic descriptions are based on aberrant individuals. However, only one of the specimens at hand which has a regenerated tail shows any obvious abnormality. Fortunately, all are adult or subadult and in good condition. The second, and perhaps more serious, restriction lies in the infeasibility of dissecting such specimens. I have indicated elsewhere (in press) the great variability of the internal characters in brotulids. It seems improbable that a sound classification of this family can ignore internal anatomy, yet it has been deemed advisable to forego investigation of most such structures in the specimens at hand.

However, if all specimens had represented the same species, no insight into brotulid variation at the specific and generic level could have been obtained. As it is, a comparison between the Hawaiian specimens has brought to light a few hitherto unused characters which may prove of value in the classification of the family as a whole.

This paper is limited to descriptive taxonomy in its narrow sense, but in the present rudimentary state of knowledge concerning the fishes of the family Brotulidae little else is possible. The best that can be hoped, therefore, is that the rather full descriptions that follow will make the specimens described identifiable to future workers and that these Hawaiian records can hence be incorporated into the groundwork necessary for any sound conclusions concerning brotulid derivation, phylogeny, and distribution.

Before the various species are described, it seems advisable to comment on two morphological characters.

One is the nature of the copulatory organ in the males of many brotulids. Hubbs (1938: 288) states, "The structure of the clasper-like penis will probably prove to be one of the most trenchant characters by which to separate the several genera of Brosmophycinae." Although I do not disagree with Hubbs's statement, I have found the character of the copulatory organ of the available male brotulids difficult to use taxonomically. In the first place, there seem to be no hard parts in this rather complicated organ, and the relative positions of its soft structures seem to depend considerably on the preservation of the specimen. Whether, as stated in the literature, this organ varies from individual to individual is impossible for me to determine, but I am inclined to believe that the observed variations are due to differences of preservation.

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Second, the organ is difficult to describe or illustrate adequately. In Figure 1, I have drawn the external features of the four Hawaiian species for which I have males with a copulatory organ.

Turner (1946: 92–96) has recently dealt in detail with the male copulatory apparatus of *Dinematichthys*, and I shall follow his terminology. In all the four species I have examined, the anus lies well forward on the midventral line of the copulatory chamber (Fig. 1*a*, *c*) and is well separated from the anal origin by the copulatory apparatus itself. In *Microbrotula*, a shallow-water genus described previously (Gosline, in press), the penis and claspers project posteriorly beyond the walls of the urogenital sinus and may be seen from below or from the side (Fig. 1*a*, *b*). The penis is elongate and bent upward in the specimen at hand so that its tip lies in part between the claspers. The claspers are relatively large.

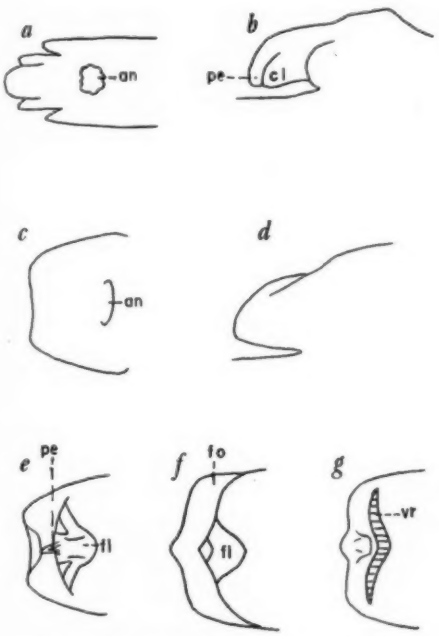

FIG. 1. Male copulatory apparatus of four species of brotulids. *a*, *b*, *Microbrotula rubra*, from below and from the side; *c*, *d*, *e*, *Diplacanthopoma* (sp.?), from below, from the side, and from above; *f*, *Diplacanthopoma* (*rivers-andersoni?*), from above; *g*, *Cataetyx hawaiiensis*, from above. The head is to the right in all figures. Abbreviations: an, anus; cl, clasper; fl, reverted flap covering the urinary opening in *Diplacanthopoma;* fo, superficial fold of skin covering genital structures in *Diplacanthopoma* (*rivers-andersoni?*); pe, penis; and ur, urinary opening.

In *Cataetyx* (Fig. 1*g*) and *Diplacanthopoma* (Fig. 1*c–f*) the copulatory apparatus is bent upward and appressed against the midventral wall of the body in such a way that its outlets cannot be seen from below or from the side. In *Diplacanthopoma rivers-andersoni?* (Fig. 1*f*) much of the area of the urogenital openings is covered by a fold of skin. Such a fold is not now present in the other specimens. In both *Diplacanthopoma* and *Cataetyx* the area of the urogenital openings is divided into two sections. Within the posterior section lies the penis. Whether this organ is exserted (Fig. 1*e*) or retracted (as apparently in *D. rivers-andersoni?*, Fig. 1*f*) seems to depend upon the circumstances at death and the nature of the preservation. The forward section is formed by the large opening of the urinary sinus, and the two sections are divided by a vertical wall which runs transversely. In *Cataetyx* the urinary sinus opens directly to the exterior, but in *Diplacanthopoma* the urinary opening is entirely covered by a reverted flap which extends from the wall separating the two sections. In neither genus are any vertical, clasper-like flaps present.

Though a far more complete knowledge of the variations in the copulatory apparatus with preservation must be gained before this structure, in the brotulids, can be used taxonomically with any confidence, it does seem that the copulatory organs of *Microbrotula* and *Dinematichthys* are of a rather different type from those of *Cataetyx* and *Diplacanthopoma*. The male organs of these last two genera can in turn be separated readily by the presence of a reverted flap covering the urinary opening in *Diplacanthopoma* and the absence of such a flap in *Cataetyx*.

The other character about which some com-

ment seems desirable is the caudal fin structure. I have shown elsewhere (in press) that the caudal fin in brotulids varies at least from a fairly normal percoid type (*Dinematichthys*) to one with a single "hypural" plate to which only four rays are attached (*Brotula* and *Microbrotula*). The species here considered all fall between these two extremes in that there are never less than 10 or more than 12 rays articulating with the last vertebra. These 10 to 12 rays are counted as the caudal rays in the present paper.

The following characters are held in common by all the brotulids treated here and will not be redescribed for each genus and species.

Body completely covered with overlapping, elliptical scales with eccentric axes. No enlarged lateral line scales. Dorsal and anal continuous with caudal. Pectoral fin undivided, with no rays greatly produced. No barbels or crests, but at least a few papillae on top and sides of head. No spines on head except on opercle and (in one species) on preopercle. Mouth subterminal. A flap of skin above opercle connected with the pectoral base. Opening behind fourth gill arch restricted. Three separate pairs of pharyngeals above and one pair below, all with small, granular teeth. Peritoneum black.

Counts and measurements for these five species are given in Table 1 rather than in the specific descriptions. The major differences between the species are summarized in Table 2. Their interrelationships and the recorded distributions of the genera to which they belong are dealt with at the end of the paper.

Genus DIPLACANTHOPOMA Günther

Diplacanthopoma Günther, 1887: 115. (Type species: *D. brachysoma* Günther, by monotypy.)

Sarcocara Smith and Radcliffe, in Radcliffe, 1913: 167. (Type species: *Diplacanthopoma* (*Sarcocara*) *brunnea* Smith and Radcliffe, by monotypy.)

Head with large muciferous channels, completely scaleless. Anterior and posterior nostrils well separated, the former opening on the snout rim, the posterior just ahead of eye. Teeth in villiform bands on jaws, vomer, and palatines; the vomerine and palatine bands very narrow. Posterior preopercular border without spines. Opercle with a spine above, ending in a sharply angulated point below. Three developed gill rakers on the first arch. Pelvic fins each of a simple filament that originates below the opercle. Pseudobranchiae represented by a pair of minute filaments or absent. Pyloric caeca absent.

The reasons for placing *Sarcocara* in synonymy are explained by Norman (1939: 79). *Myxocephalus* and *Saccogaster* appear to be closely related to *Diplacanthopoma* and are perhaps not generically distinct.

Most of the seven known species of *Diplacanthopoma*[3] have been inadequately described, probably due in part to the poor condition of the specimens upon which the descriptions were based. Scale count, for example, is given for only one of the seven species and fin counts for only two. The described species have been differentiated from one another (where they have been differentiated at all) by such features as the shape and size of the head, the size of the eye, and the standard length. As a result, it is impossible to tell from existing descriptions (and probably from re-examination of the type specimens) how many of these seven species are valid. Furthermore, all the species have been described from one or a few specimens, so that the nature of the individual variation within species in this genus remains unknown. Until abundant and topotypic material of these species becomes available, there seems no way of determining with any as-

[3] *Diplacanthopoma jordani*, described from near the Galapagos Islands by Garman (1899: 160), is not mentioned in Norman's list of deep-water brotulid species (1939: 84–92), nor can I find other mention of it in the literature. In any event, *D. jordani* is described in hopelessly unrecognizable fashion; no figure, no generic characters, no fin-ray or scale counts, not even the length of the type is given.

TABLE 1

MEASUREMENTS* AND COUNTS OF HAWAIIAN DEEP-WATER BROTULIDS

	Diplacanthopoma (riversandersoni?)	*Diplacanthopoma* (sp.?)	*Cataetyx hawaiiensis*	*Volcanus lineatus*	*Pycnocraspedum armatum*
Standard length (in millimeters)	292	135+	222	267	302
Depth at anal origin	124	(262)	168	150	227
Snout to dorsal origin	295	(646)	359	318	195
Snout to pelvic origin	272	(591)	224	207	213
Snout to anal origin	473	75.8[mm.]	487	494	454
Pelvic origin to anal origin	256	(525)	280	293	260
Head to end of opercular flap	261	(579)	283	240	255
Postorbital head length	167	(355)	178	150	154
Length of upper jaw	116	(263)	136	109	143
Snout	61	(142)	70	64	65
Fleshy interorbital	77	(153)	55	33	77
Eye	41	(103)	39	33	44
Distance between ends of free preopercular border	50±	(145±)	75±	75±	95±
Distance between anterior and posterior nostril	24	(66)	49	13	16
Greatest width of premaxillary tooth band	11	(16)	7	10	13
Length of premaxillary tooth band	99	(199)	94	83	122
Greatest width of mandibular tooth band	8	(13)	6	9	10
Length of mandibular tooth band	82	(183)	102	83	97
Greatest width of vomerine tooth band	3	(12)	6	7	10
Length of vomerine tooth band	37	(78)	37	30	35
Greatest width of palatine tooth band	3	(13)	5	10	4
Length of palatine tooth patch	...	(91)	...	48	56
Length of longest pelvic filament	147	(343)	118	151	115+
Length of pectoral fin	130±	(275+)	110+	105	157
Length of caudal fin	58	...	87	82	99
Length of longest dorsal ray	110±	(198)	51	52	85
Greatest height of fleshy membrane on dorsal base	15	(30)	40	...	58
Transverse scale rows	140±	126+	200±	175±	135±
Transverse scale rows ahead of anal origin	47±	48±	50±	72±	40±
Scales above lateral line	11±	11±	17±	16±	20±
Scales below lateral line	27±	34±	34±	35±	47±
Predorsal scales	29	38	48	44	9
Dorsal rays	163±	130+	88±	89±	90±
Anal rays	111±	95+	67±	77±	72±
Caudal rays	10	...	11	12	10
Pectoral rays	26	28	25	26	26
Pelvic filaments	1	1	1	2	2
Developed gill rakers	3	3	3	3	5–6
Branchiostegal rays	8	8	7	8	8

* Measurements, except standard length, are given in thousandths of the standard length. However, for *Diplacanthopoma* (sp.?), which has lost the posterior tip of the body, measurements are given in thousandths of the distance from the snout to the anal fin origin. A + alone indicates that the actual value is at least as great as the figure.

TABLE 2

SUMMARY OF DIFFERENCES BETWEEN FIVE HAWAIIAN DEEP-WATER BROTULIDS

	Diplacanthopoma (*rivers-andersoni?*)	*Diplacanthopoma* (sp.?)	*Cataetyx hawaiiensis*	*Volcanus lineatus*	*Pycnocraspedum armatum*
Standard length in millimeters	292	135+	222	267	302
Head					
Head length in snout–anal distance	1.8	1.7	1.7	2.1	1.8
Eye diameter in fleshy interorbital	1.9	1.5	1.4	1.0	1.8
Distance from eye to posterior nostril in distance between nostrils	2.3	2.6	6.0	0.6	4.4
Position of anterior nostril	on snout rim	on snout rim	on snout rim	behind snout rim	behind snout rim
Structures along snout rim	elongate cavities alternating with narrow fleshy bridges	as in *D.* (*rivers-andersoni?*)	with large pores	with several small flaps	without pores or flaps
Preopercular spines	absent	absent	absent	absent	present
Opercle	pointed below	pointed below	not pointed below	not pointed below	not pointed below
Head squamation	head totally scaleless	head totally scaleless	scaled except for isthmus, maxillary, lips, and front of snout	about as in *Cataetyx*	completely scaled except for lips
Tooth size	some of teeth slightly enlarged	some of teeth slightly enlarged	some of teeth considerably enlarged	none of teeth enlarged	none of teeth enlarged
Vomerine teeth	in a continuous band	in a continuous band	with a median, toothless interspace	in a continuous band	in a continuous band
Tongue	not reaching vomer	not reaching vomer	protruding between vomerine tooth patches	not reaching vomer	reaching to below vomer
Teeth on branchial arches below	none	patches at base of each third gill arch	none	a short median band; lateral patches at bases of each third gill arch	a long median band; no lateral patches

TABLE 2—Continued

SUMMARY OF DIFFERENCES BETWEEN FIVE HAWAIIAN DEEP-WATER BROTULIDS

	Diplacanthopoma (*rivers-andersoni?*)	*Diplacanthopoma* (sp.?)	*Cataetyx hawaiiensis*	*Volcanus lineatus*	*Pycnocraspedum armatum*
Developed gill rakers	3	3	3	3	5–6
Branchiostegal rays	8	8	7	8	8
Body					
Snout–anal distance in standard length	2.1	...	2.1	2.0	2.2
Lateral line structure	separate papillae	separate papillae	separate papillae	a continuous fleshy tube along surface of body	a continuous fleshy tube along surface of body
Lateral line position	two unconnected lines which between them run the length of the fish	as in *D.* (*rivers-andersoni?*)	as in *Diplacanthopoma* except that there is a rudimentary third line	single, incomplete, terminating about below dorsal origin	single, almost reaching posterior end of body
Pyloric caeca	absent	absent	a single, flap-like appendage	absent	about a dozen finger-like appendages
Fins					
Dorsal origin	slightly behind pectoral bases	slightly behind pectoral bases	slightly behind pectoral bases	well behind pectoral bases	about over preopercular border
Hypural	single, narrow, undivided	...	single, broad, divided	two broad hypurals	single, broad, divided
Scales on vertical fins	absent	absent	absent	present	present
Scales on pectoral rays	absent	present	present	present	present
Spine above pectoral base	absent	present	a small, blunt spine	absent	absent
Ventral filaments	simple	simple	simple	bifid	bifid

surance what names should be applied to the *Diplacanthopoma* specimens at hand.

It would be an easy matter (and one for which the precedent has already been set in *Diplacanthopoma*) to describe the Hawaiian species as new. However, I can see no advantage in doing so at present. It would appear preferable to describe the Hawaiian specimens sufficiently for specific recognition, leaving the names to be applied to them to the time when the genus can be revised on a world-wide basis.

The two specimens in the present collections appear to represent two species. It is true that most of the differences between them could be attributed to discrepancies in preservation, to size, to the regeneration of the tail in one, or to individual variation. There are, however, a few characters that apparently could not be attributed to any of the above categories.

Diplacanthopoma (?rivers-andersoni Alcock)

Tables 1, 2; Figs. 1*f*, 2*a*, 3*a*

?Diplacanthopoma Rivers-Andersoni Alcock, 1895: 144 (Arabian Sea); Alcock, 1895?, pl. 17, fig. 1 (from the holotype); Alcock, 1899: 98–100 (on the holotype); Norman, 1939: 91 (species listed).

MATERIAL EXAMINED: 1 male, 292 mm. in standard length, taken off the Mauna Loa lava flow, Hawaii, by Gosline, Hayes, Keen, and Ellis, June 6, 1950.

Body tapering to a rather fine point posteriorly, the 10 caudal rays articulating with a single, undivided hypural and forming a very narrow, pointed tail. Head large, subcylindrical, entirely scaleless. Maxillary reaching about to level of posterior border of eye. Posterior nostril a large hole just ahead of eye, partially covered over in front by a flap of skin. Anterior nostril in a short tube at rim of snout. Large sinuses on head: one under each ramus of lower jaw, a second below preopercle, a third within the fleshy flap above the opercle, all these sinuses inflated in this specimen. Snout rim, from beside premaxillary pedicels to about opposite middle of eye, with an elongate, slit-like cavity, closed over at two points by narrow, fleshy bridges. Free preopercular border somewhat angular below, but without developed spines. Lower points of opercle not penetrating flesh.

Teeth all small but not of equal size, some

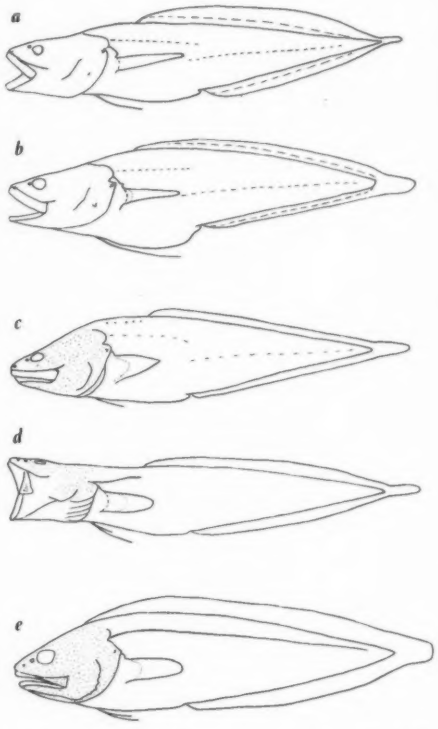

FIG. 2. *a*, *Diplacanthopoma* (*rivers-andersoni?*); *b*, *Diplacanthopoma* (sp.?); *c*, *Cataetyx hawaiiensis; d*, *Volcanus lineatus; e*, *Pycnocraspedum armatum*. Scaled portions of head are indicated by stippling. The limit of the scaly lobe on the pectoral fin base is shown by the dotted line. The limits of the fleshy sheaths along the bases of the dorsal and anal in *Diplacanthopoma* are shown by broken lines. The lateral lines of the body are shown in three ways: the superior, rudimentary line of *Cataetyx* by dots; developed lateral lines consisting of papillae penetrating the scales by dashes; and continuous, fleshy tubes running along the surface of the body by solid lines.

granular, some sharply conical. No teeth on tongue or branchial arches. Lower pharyngeal tooth-patches widely separated. Premaxillary bands separated by a slight interspace at symphysis. Vomerine teeth in a continuous, narrow band. Palatine band very narrow, practically two-rowed. Tongue a short, blunt knob, which does not extend as far forward as the vomer. Slit behind fourth gill arch very small. Pseudobranch represented by a pair of minute filaments on one side, but apparently absent on the other.

Lateral line composed of small papillae that penetrate the scales at intervals; in two sections, the anterior straight and well dorsal on the back to about the level of the anus, the posterior mid-lateral from above the anal origin to the end of the body, becoming less prominent posteriorly.

Dorsal originating nearly an eye diameter behind the pectoral axil, the rays, as in the anal, increasing gradually in length to near the tail. Dorsal and anal with a scaleless basal sheath of skin which covers the greater part of each of the first rays but which decreases in width posteriorly, terminating slightly ahead of the tail.

Pectorals with the rays graduated in such a way as to give the fin a somewhat tapering point above the middle. Base of pectoral fin with a scaleless, lobate sheath which contrasts strongly with the scaled lobe from which the pectoral base projects. Pelvics originating approximately under the lower point of the opercle, each of a simple filament which is apparently composed of two fused rays.

Copulatory lobe present (Fig. 1*f*). Air bladder present.

Body brownish. Head and fins bluish black.

The specimen described above appears to differ from *D. brachysoma* Günther (1887: 115) in a number of minor respects. *D. brachysoma* is said to have the eye equal to the interorbital width; the specimen at hand has the eye considerably less than the interorbital width. (However, the Hawaiian specimen is considerably larger than the type and only specimen of Günther's species.) Also, the dorsal fin of *D. brachysoma* seems to originate farther forward than that of the Hawaiian specimen, and no basal, fleshy sheaths along the dorsal and anal are described or figured for *D. brachysoma*.

D. rivers-andersoni Alcock (1895: 144) is the second species to be described in the genus. Though there are several descrepancies between Alcock's description and plate and the specimen at hand, I can find none that seem to be of certain specific validity. Alcock's plate shows enlarged scales along the front of the lateral line, but, as most of the scales in Alcock's specimen appear to have been lacking, I am not sure that this is not an artist's artifact. The head of the Hawaiian specimen appears to be somewhat larger (but Alcock's specimen was larger), and there is no scaleless membrane figured or described on the base of the pectoral fin of *D. rivers-andersoni*. (As in *D. brachysoma*, no fin-ray or scale counts are given for Alcock's species.)

From *D. brunnea* Smith and Radcliffe (Radcliffe, 1913: 167), the Hawaiian specimen differs distinctly in the more numerous fin rays.

D. raniceps Alcock (1898: 154), *D. alcocki* Goode and Bean (1895: 528), *D. jordani* (1899: 160), and *D. nigripinnis* Gilchrist and von Bonde (1924: 20) are inadequately described species about which little can be said.

Diplacanthopoma (sp.?)

Tables 1, 2; Figs. 1*c–e*, 2*b*, 3*b*

MATERIAL EXAMINED: 1 male, 135 mm. in standard length, collected off the Mauna Loa lava flow, Hawaii, by Moore *et al.*, June 3, 1950.

This specimen has a regenerated tail, and its standard length, lateral line scale count, and dorsal and anal count are consequently all abnormal, i.e., too low. In general, the specimen is in a better state of preservation than that of *D.* (*rivers-andersoni?*), with fewer scales lost, the mucous sinuses on the head and the fleshy sheaths at the bases of the fins less bloated, etc. The fish, however, has died with the gill covers widely flaring and the

isthmus pushed up against the roof of the mouth, giving the head a flattened appearance as compared with *D.* (*rivers-andersoni?*). I believe this apparent difference is due to the manner of preservation and that the head shapes of the two species are actually very similar.

The differences in counts and measurements of the two Hawaiian species of *Diplacanthopoma* are given in Table 1. Among these the most marked discrepancies are the somewhat larger head and eye, the longer ventral filaments, and the more numerous predorsal scales in *D.* (sp.?). However, more significant structural differences are also present. In *D.* (sp.?) the cleithrum just above the pectoral base projects backward as a sharp point which can easily be felt through the skin; in *D.* (*rivers-andersoni?*) there is no such point. In *D.* (sp.?) the basal part of the pectoral fin rays are scaled; in *D.* (*rivers-andersoni?*) there are no scales on the base of the pectoral rays, though a fleshy sheath extends on to the fin. Again, in *D.* (sp.?) there is a patch of teeth at the base of the third gill arch on each side; in *D.* (*rivers-andersoni?*) there are no such patches. Finally, in the latter species the lower pharyngeals appear to be much more widely separated than in *D.* (sp.?). Aside from these differences, the description of *D.* (*rivers-andersoni?*), given above, will apply equally well to *D.* (sp.?).

D. (sp.?) appears to differ from *D. brachysoma* in about the same way that *D.* (*rivers-andersoni?*) does, but I cannot with any certainty distinguish it from any of the other six described species in the genus. Indeed, it is quite possible that this specimen, and not the one I have provisionally called *D. rivers-andersoni*, represents that species.

Genus CATAETYX Günther

Type species: *Cataetyx messieri* Günther (1887: 104), by monotypy.

The genus *Cataetyx* has been interpreted very broadly by Norman (1939: 83) as including those brotulids with the following characters:

Head low, more or less depressed. Opercles and cheeks scaled. Interorbital region and preopercles without spines. Snout and lower jaw without barbels. Vomer and palatines toothed. No canine teeth. Two to five developed gill rakers on the first arch. Body scaled, not very tapering posteriorly. Lateral line present, double, inconspicuous. Caudal united with dorsal and anal, dorsal with more than 90 rays, anal with more than 70. Tips of cleithra firmly united. Pelvics each of a simple filament originating behind eye. Flap-like appendages near pylorus.

Within the genus *Cataetyx* as thus defined, the species *C. messieri*, *C. rubrirostris*, the species described below, and perhaps *C. laticeps* (of which the teeth are said only to be "in viliform bands," Koefoed, 1927: 137) would seem to form a closely related group.[4] These may be differentiated from other species included in the genus by Norman (1939: 90) by having the head scaled to forward of the eyes and some enlarged teeth on the sides of the mandibles and on the vomer and palatines. Whether the genus should be restricted to such species, I do not have the material to determine. Under any circumstances, however, *Pteridium alleni* Byrne does not appear to belong in *Cataetyx*, where it was placed by Norman (*loc. cit.*).

Cataetyx hawaiiensis n. sp.

Tables 1, 2; Figs. 1*g*, 2*c*, 3*c*

Holotype: U. S. N. M. 162715, a male 222 mm. in standard length, collected off the Mauna Loa lava flow, Hawaii, by Gosline, Hayes, Keen, and Ellis, June 6, 1950.

Body tapering to a rounded point posteriorly, covered with nonembedded, overlap-

[4] Another species which may belong in this group but which is impossible to place from the description is *Oculospinus brevis* Koefoed (1927: 138). Koefoed's new genus (*Oculospinus*) and both of his new species have been omitted from Norman's "Synopsis" (1939: 79–92).

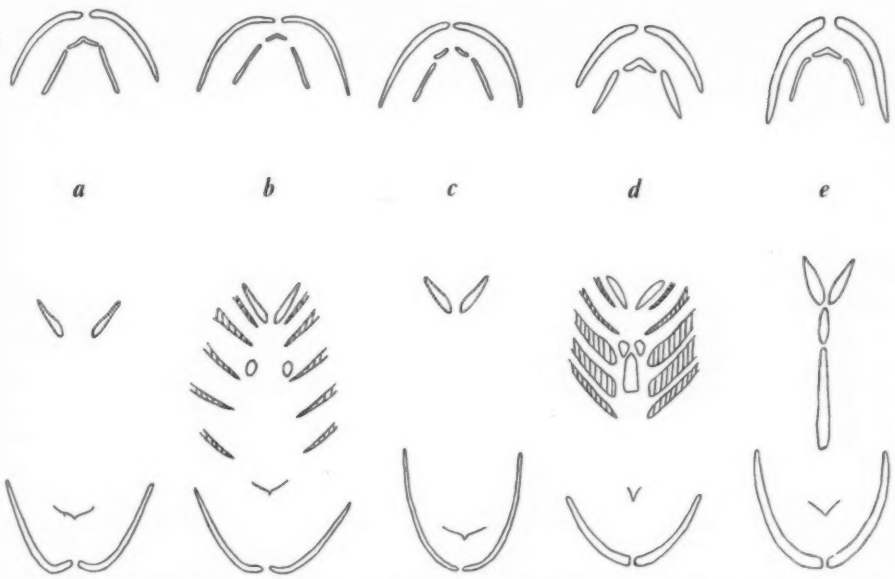

FIG. 3. *a*, *Diplacanthopoma* (*rivers-andersoni*?); *b*, *Diplacanthopoma* (sp.?); *c*, *Cataetyx hawaiiensis; d*, *Volcanus lineatus; e*, *Pycnocraspedum armatum*. Above, tooth bands of upper jaw and roof of mouth; below, tongue and tooth bands of lower jaw and on lower half of gill arches. Upper pharyngeals and spinous gill rakers omitted. The bases of the gill slits are shown (hatched) in two species. Certain differences in the relative position of the parts, e.g., whether or not the gill covers are widely flaring, are undoubtedly caused by differences in preservation.

ping scales. Eleven caudal rays articulating with a single, medianly incised hypural plate.

Head depressed forward, eyes high on snout and directed more superiorly than laterally, covered with scales except for isthmus, lips, maxillaries, and area around rim of snout. No spines on head except for single opercular spine. Maxillary extending about half an eye diameter beyond eye, largely concealed by suborbitals when mouth is closed. Posterior nostril a large hole near front of orbit and slightly below level of middle of eye. Anterior nostril over snout rim. Snout with three enlarged pores on either side in front just above rim; two pores near lower border of suborbitals; a pore on mandibles on either side of isthmus under jaw bone; about three pores along rami of hyoid arch, and one on lower border of preopercle. Free preopercular border more or less rounded, spineless. Opercle not ending in a sharp point below. Flap above opercle covered with minute scales.

Teeth in upper jaw in a villiform band; laterally, teeth increase somewhat in size from outer to inner row. Mandibular rami raised posteriorly, their teeth in long bands. In front the mandibular teeth are in about a half dozen rows, outer three or four small, inner somewhat enlarged. Laterally, teeth in two rows, inner consisting of sharply conical teeth several times as large as those of outer row. Posteriorly, outer row of small teeth drops out leaving only a single row of enlarged teeth, this row continuing well behind premaxillary rows. Vomer with two patches of teeth separated by a median interspace under which the tongue protrudes; each patch consists of about a dozen slightly curved, conical teeth. Palatines with long band of conical teeth less than half the size of those on vomer, with inner rows larger than outer. No teeth on tongue or on bases of the four gill arches.

Lateral line in two sections, with some evidence of a supplementary third section above in front. This uppermost line consists of about six papillae running along either side of nape from behind the occiput to just in front of level of dorsal origin. Upper major lateral line running backward from lobe above opercle, following contour of back and then bending downward posteriorly, ending above origin of about fifth anal ray. Lower lateral line commencing above anal origin and continuing along mid-sides almost or quite to posterior end of body. All three lateral lines apparently composed of papillae that project through the scales.

Vertical fins scaleless, but a lobe of scales projecting on to base of pectoral. Dorsal originating well behind pectoral base, its rays, and also those of anal, all low but highest about middle of fin. Dorsal and anal rays enclosed in skin for most of their length, but this fleshy sheath not forming a prominent band as in *Diplacanthopoma*. Caudal rays projecting well beyond dorsal and anal rays. Pectorals badly frayed, but apparently short and broad. Just above pectoral base a blunt, concealed, backwardly directed point on cleithrum. Pelvics originating under preopercle, reaching less than half way to anus.

A single, short, pointed, pyloric appendage. No pseudobranch.

Head and pectoral base bluish black. Body brownish. Pectoral rays and membranes enclosing bases of dorsal and anal black. Projecting sections of dorsal and anal light.

C. hawaiiensis differs from *C. messieri* Günther in a number of minor respects. The anus is well forward of the middle of the standard length in *C. hawaiiensis* (it is median in *C. messieri*). The head appears to be flatter and broader forward, with the eyes more upwardly directed than in Günther's species. The eyes are also nearer the front of the head, so that the snout plus eye (measured over a horizontal plane for comparison with Günther's plate) is contained about two times in the postorbital head against about 1.6 times in Günther's plate of *C. messieri*. The head length is considerably more than half the distance from snout tip to vent in *C. hawaiiensis*, less than half that distance in *C. messieri*. The dorsal origin lies behind the mid-point between snout and vent in *C. hawaiiensis*, over it in *C. messieri*. Finally, the dorsal and anal of the Hawaiian species seem to differ in being lower, in having fewer rays, and in being scaleless (Günther's plate of *C. messieri* shows scales on the bases of the vertical fins).

Cataetyx hawaiiensis differs from Gilbert's description of *C. rubrirostris* (in Jordan and Evermann, 1898: 2505) in two major features and in dimensions. In *C. hawaiiensis* there is no "short, sharp spine directed backward immediately behind posterior nostril"; instead, the posterior nostril opens out from what appears to be a bony trough just in front of the eye with a single row of scales separating this nostril from the orbit. In *C. rubrirostris* there are said to be "about 135 transverse series" of scales; in *C. hawaiiensis* the scales are more or less regularly arranged, and many of them have been lost from the holotype; nevertheless, four counts made of the transverse series ranged from 190 to 235 scales. In dimensions *C. rubrirostris* would appear to have a larger eye, shorter snout, and narrower interorbital.

In the shape of the head *C. hawaiiensis* resembles *C. laticeps* Koefoed (*loc. cit.*) more than it does *C. messieri*. But *C. laticeps*, like *C. messieri*, is said to have the anus under the middle of the standard length rather than far forward as in *C. hawaiiensis*. In addition, *C. laticeps* is said to have the posterior nostril well in front of the eye and to have nine branchiostegal rays (seven in *C. hawaiiensis*).

Genus VOLCANUS nov.

Type species: *Volcanus lineatus* n. sp.

Body tapering, but with a truncated posterior tip at the end of the two well-developed hypurals. Caudal rays considerably exserted. Lateral line single, incomplete, running along surface of body as a continuous fleshy tube

from flap above opercle about to below dorsal origin. Scales of sides of body with more or less randomly scattered pores, some along mid-sides perhaps representing rudiments of a lower lateral line.

Top of head scaled to in front of eyes; rami of lower jaw, branchiostegal membranes, and maxillary partially scaled; snout in front, lips, lower border of suborbitals, and isthmus completely scaleless. Snout rim bordered by three or four fleshy, leaf-like flaps on either side. Six hair-like lines running backward over scaleless area of snout on each side, forming slight fleshy ridges. No crests or spines on head except for a single, weak opercular spine. Posterior nostril well ahead of eye, about midway between anterior orbital rim and anterior nostril, which exits from a tube well back from snout rim.

Small, granular, pavement-like teeth in short, broad, continuous bands on premaxillaries, mandibles, and vomer. Tongue relatively elongate and pointed but not reaching as far forward as vomer. Two developed gill rakers below and a third at angle of first arch. Pseudobranch reduced to two small filaments on one side and one on the other.

Pelvic fins composed of two filaments each, these divided nearly to their base and originating below the opercle, the outer about half the length of the inner. Pectoral apparently short and rounded, undivided, a scaly basal lobe extending out about two fifths the length of the fin. No sharp point on cleithrum above pectoral base. Dorsal commencing about two thirds of the way out along the depressed pectoral fin. Dorsal, anal, and caudal scaled basally.

Judging from Norman's key (1939: 80–84), *Volcanus* is most closely related to *Luciobrotula* Smith and Radcliffe (Radcliffe, 1913: 170). It differs, however, in lacking a lower opercular spine, in having an incomplete lateral line which is developed as a fleshy tube between and above the scales, and apparently in the peculiar arrangement of flaps and lines on front of snout. Upper part of suborbitals and area between posterior nostril and eye apparently unscaled in *Luciobrotula*, but scaled in *Volcanus*.

Volcanus also bears a superficial resemblance to *Bassogigas* and *Neobythites* but differs at once from these genera in the fewer developed gill rakers and the less complete squamation of the head.

Volcanus is named for Vulcan, the Latin fire god, to whom I am much indebted for sending this fine fish collection.

Volcanus lineatus n. sp.

Tables 1, 2; Figs. 2*d*, 3*d*

HOLOTYPE: U. S. N. M. 162716, a female 267 mm. in standard length, collected by Moore *et al.*, June 3, 1950, off the Mauna Loa lava flow, Hawaii.

The holotype at present has the head thrown back and the gill covers widely flaring. It is more or less impossible to judge the head shape in life. However, the head appears to be relatively small, its length about equal to its distance from the anus. The eyes seem to be on the dorsolateral surface of the head and are separated by a flat interorbital. The posterior nostril is a semicircular hole with the median rim straight. Just posteromedially of this nostril a narrow, linear fleshy ridge commences (resembling a thin barbel attached to the surface of the head for its entire length) which runs back along the upper rim of the orbit. There are four or five scale rows encircling the eye below and in front, except for the area of this ridge. Scaleless area of front of snout with other, similar, longitudinal ridges. Rim of snout with small, overlapping, leaf-like appendages. Maxillary reaching about half an eye diameter beyond eye, with a small patch of about six scales posteriorly. Suborbital rim double for most of its length, with about three inconspicuous pores along its lower edge. Mandibles covered below by a series of assorted scales, fleshy ridges similar to those on front of snout, pores, and pockets with papillae in center. Top of head posteriorly, and to some extent the cheeks, with

fleshy papillae as well as scales. Free preopercular border somewhat angled but without spines. Opercle with a single weak spine above, which does not protrude through the flesh, and no indication of a spine at its lower angle. Teeth uniformly small, granular; the vomerine band of teeth in a widely flaring V of equal width throughout. There is a broad, median patch of teeth between the bases of the second gill arches which extends almost from the bases of the first to the bases of the third. Posterolaterally to this there is a patch of teeth on each side lying on the front surface of the bases of the third gill arches.

Dorsal origin less than a head length behind occiput, the dorsal rays increasing in length to about two thirds of the distance to the tail, then decreasing to the caudal base. Anal rays shorter than dorsal rays and more nearly equal in length throughout the fin. Pelvics originating close to one another and to the symphysis of cleithra, somewhat scaled at base.

The holotype and only specimen has the ovaries somewhat distended and filled with very numerous small eggs. No pyloric appendages.

More or less uniformly brownish on body shading into bluish black on fins, head, and belly.

The trivial name *lineatus* (L.—lined) is given in reference to the linear fleshy ridges on the front of the snout and on the lower jaw.

Genus PYCNOCRASPEDUM Alcock

Tables 1, 2; Figs. 2*e*, 3*e*

Type species: *P. squamipinne* Alcock (1889: 386), by monotypy.

Body tapering to a truncate point. Caudal distinguishable from dorsal and anal by closer grouping of last 10 rays, these not much exserted and articulating with a medially incised hypural plate. Lateral line single, straight, continuing almost to posterior end of body, lying in a fleshy tube which extends over surface of, or between, scales for its entire length.

Top of head completely scaled to snout rim. Maxillaries, rami of lower jaw, isthmus, and branchiostegal membranes scaled; only the lips scaleless. Rim of snout forming a smooth, continuous rim unbroken by pores or flaps; a few relatively small pores opening out above rim. Pores on mandible and cheeks inconspicuous; mucous sinuses not apparent. A few fleshy papillae on head, apparently over sensory canals. Opercle with a single sharp point above, the exserted point completely surrounded by scales; apparently, opercle does not form a point below. Small, scaly lobe above opercle.

Posterior nostril opening out into a low, flat collar just ahead of eye; no scale rows between it and eye. Anterior nostril in a tube about halfway between posterior nostril and snout rim.

Uniformly small, granular teeth on premaxillaries, mandibles, vomer, and palatines. Vomerine teeth in a continuous, broadly V-shaped patch under which lie the small, pointed tongue, medianly, and the wings of the hyoid arch, laterally. Three or four developed gill rakers below and another at angle of first arch. Pseudobranch rudimentary.

Dorsal originating over gill cover. Dorsal and anal rays longest just ahead of tail and covered for the greater part of their length with scales. Pectorals fairly long, scaled basally. Pelvic fins each of two filaments which are united basally, separate distally, outer filament about two thirds as long as inner. Pelvic origin below preopercle, considerably behind symphysis of cleithra.

Pycnocraspedum armatum n. sp.

Tables 1, 2; Figs. 2*e*, 3*e*

HOLOTYPE: U. S. N. M. 162717, a female 302 mm. in standard length, collected off the Mauna Loa lava flow, Hawaii, by Hayes and Burke, June 3 and 4, 1950.

The general appearance of this fish is quite *Brotula*-like (except for the absence of barbels) with compressed, scaled head and the vertical fins with high, scaled, but poorly delimited,

fleshy sheaths. Head length greater than its distance from anus. Eyes lateral, with maxillaries reaching almost an eye diameter beyond them. Snout without flaps or ridges, anterior nostril well back from its edge. Preopercle with four sharp points, between which the preopercular border is scalloped.

Basibranchials with an almost continuous, median band of teeth of even width (divided into two sections above bases of third gill arch) running from base of tongue almost to base of lower pharyngeals, which are close together.

About a dozen, finger-like pyloric caeca.

This specimen appears to be a female with small, undeveloped ovaries. The specimen either had spawned recently or it represents the immature form of a rather large species.

Pycnocraspedum armatum differs distinctly from *P. squamipinne*, the only other known species in the genus, in having well-developed, sharp points on the preopercular border. Alcock (1899: 84) says that *P. squamipinne* has "two or three rather indistinct points at the angle of the preoperculum," but only one is shown in his plate (1895?, pl. 21, fig. 1). In addition, the dorsal fin of *P. armatum* originates forward of (rather than behind) the preopercular border, and the pectoral fin reaches about to the anus.

The trivial name *armatum* (L.—armed) is given in reference to the spines on the preopercular border.

INTERRELATIONSHIPS OF HAWAIIAN DEEP-WATER BROTULIDS

In a family as large and varied as the Brotulidae, it is perhaps presumptuous to try to determine interrelationships from the five species at hand. Yet, to fail to do so would seem to be making incomplete use of available material, scanty as it is. The following brief discussion is therefore undertaken, with the full realization that any conclusions reached must remain highly provisional. The bases for these conclusions are summarized in Table 2.

The five brotulids in the lava flow collections would seem to fall into three groups: (1) the two species of *Diplacanthopoma*; (2) *Cataetyx*, and (3) *Volcanus* and *Pycnocraspedum*. Arranged in this way, these brotulids form a series ranging from those with the head completely scaleless (*Diplacanthopoma*) to *Pycnocraspedum* with the head entirely scaled. On this character alone *Volcanus*, with the head partially scaled, would fall with *Cataetyx*, as it would if gill raker count, dorsal fin origin, or preopercular armature were used. However, I feel that *Volcanus* is more closely related to *Pycnocraspedum* because of similarities between these two genera in dentition, the position of the anterior nostril, the lateral line structure, and, to a slight extent, because of the development of a bifid pelvic filament.

In the general classification of the family as erected by Radcliffe (1913) and Norman (1939), *Pycnocraspedum* occupies a somewhat dubious position somewhere between the oviparous forms with a fully scaled head and rather numerous well-developed gill rakers, and the viviparous forms with the head partially scaled or naked and only three developed gill rakers (see Norman, 1939: 89).

Unfortunately, whether *Pycnocraspedum* is oviparous or viviparous remains unknown. The same is true of *Volcanus*, though the numerous small eggs of the holotype of *V. lineatus* bear far more resemblance to the eggs of the oviparous *Brotula* than they do to the few large eggs of the viviparous *Dinematichthys* and *Microbrotula*. Indeed, *Brotula* itself demonstrates that there are oviparous brotulids with the head completely scaled and the developed gill rakers reduced to three.

In view of these points the contingency is presented that between the "oviparous" and "viviparous" groups as drawn up by Norman (1939, key sections C and CC, pp. 80 and 82) there lies an intermediate group of oviparous genera with the head more or less fully scaled and the number of gill rakers more or less reduced. Such a possibility is not pleasant for makers of keys to brotulid genera to con-

template. However, whether or not such an intermediate group is discovered eventually, it seems probable that a more thorough knowledge of the internal and external characters of brotulid genera will make necessary a rather drastic revision of any classification that has hitherto been erected.

GEOGRAPHIC AND BATHYMETRIC RELATIONSHIPS OF HAWAIIAN DEEP-WATER BROTULIDS

The fact that none of the five Hawaiian species of deep-water brotulids can be certainly allocated to hitherto described forms is striking. It could indicate an endemic Central Pacific brotulid fauna. In the light of shallow-water fish distribution—including that of *Brotula multibarbata*, which ranges from South Africa to Hawaii—this seems improbable. Or it might indicate that the Mauna Loa lava flow has brought to the surface wide-ranging brotulids that live in habitats heretofore unsampled. However, in view of the fact that most of the other described brotulids have also been taken only once, it most probably serves merely as a further demonstration of how inadequately brotulids have been collected. If this last is the correct explanation, the inference is that the Brotulidae will eventually prove to be one of the larger fish families.

Turning to genera, *Volcanus* has been hitherto unknown. The distribution of the species presumably related to the Hawaiian species of the other three genera is shown in Table 3. Aside from pointing out the wide extent and variety of these generic distributions, little can be said. *Cataetyx hawaiiensis* suggests affinities with the tropical West American fauna and *Pycnocraspedum armatum* with that of the Indian Ocean, but in the present state of knowledge such suggestions are purely tentative. Perhaps a more curious aspect of the Hawaiian forms is their almost complete lack of affinity with the best known of brotulid faunas—that of the Philippines (Radcliffe, 1913).

TABLE 3
DISTRIBUTION OF SPECIES RELATED TO THE HAWAIIAN DEEP-WATER BROTULIDS

SPECIES	LOCALITY	DEPTH
		Fathoms
Diplacanthopoma		
brachysoma	Brazil	350
rivers-andersoni	Arabian Sea	947
raniceps	Andaman Sea, Gulf of Aden	405–600
alcocki	Andaman Sea	490
jordani	Galapagos	385
brunnea	Philippines, Arabian Sea	375–1,050
nigripinnis	Natal	700
Cataetyx		
messieri	Chile	345
rubrirostris	California	205–359
Pycnocraspedum		
squamipinne	Bay of Bengal, Zanzibar	130–250

Regarding depth distribution, Table 3 indicates *Pycnocraspedum* to be a shallower-water genus than *Cataetyx* or *Diplacanthopoma*. In line with this, the Hawaiian specimen of *Pycnocraspedum* was among the earliest of the fishes collected after the lava flow entered the water. It also maintains a brownish coloration, whereas the others range from gray to blue black.

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Report on a Trip to Marcus Island with Notes on the Birds

NAGAHISA KURODA[1]

MARCUS ISLAND, situated about midway between the Bonin Islands and Wake Island in the western Pacific, is a small, remote island which belonged to Japan until World War II and is known to the Japanese as Minami Torishima, the South Bird Island. It is now in the possession of the United States, but a Japanese weather station, constructed after the war, is the only establishment on the island.

A zoological survey of this island was planned by Hokkaido University, which sent Mr. M. Yamada (for the litoral invertebrata) and Mr. S. Sakagami (for the insects). I joined them to make bird investigations, through the kindness of Professor T. Uchida, Hokkaido University, Dr. S. Wadachi, head of the Central Weather Station, and other gentlemen of the Station—Mr. N. Yamada, the Chief Secretary, Mr. Y. Nakada, head of the Marcus Island Section, Mr. T. Doi, the head, and Mr. S. Kitada, the secretary, of the Supply Section, and other people concerned. My cordial thanks are due these gentlemen and also Dr. H. E. McClure of the 406th Medical General Laboratory in Tokyo.

Taking advantage of the supply ship, "Kuroshio-maru" (450 tons), in charge of the Central Weather Station of Tokyo, we left Tokyo Harbor on April 25, 1952, arrived at Marcus Island on April 30, and stayed for a week until we embarked on May 7 to return to Tokyo. It was an intergrading season, the weather ranging from winter to summer type, and the sea was rough with N.N.E. winds which prevailed in about 4-day cycles, alternating with a summer wind from S.–S.S.W. which calmed the sea and brought hot atmosphere. Navigating southward through latitudes of about 28–33° N., far east by south of Hachijo Island, the change of temperature and the color of the sea showed the demarcation between temperate and semi-tropical waters. The southerly rear-guards of the Black-footed Albatross, *Puffinus carneipes*, Storm-Petrels, and Skuas, which were migrating to the temperate zone, were already in the cooler area north of the aforementioned latitudes. To the south, tropical species such as *Puffinus nativitatis* and *Pterodroma* were encountered. Sea birds in general, however, were scarce, the main group of oceanic migrants having passed north already, and the tropical species were probably concentrated around the breeding islands. Only the following species were seen en route:

Oceanodroma tristrami (or **matsudairae**)

A few were seen scattered over the ocean and followed the ship but were distributed north of about 27–28° N.

Oceanodroma castro (or **leucorhoa**)

Two were observed closely on May 10 at about 33° N.

Puffinus leucomelas

Many were observed near the mouth of Tokyo Bay on April 26, and a few were seen north of 30° N. on May 10.

Puffinus carneipes

Six birds in all were seen north of about 33° N. on May 10.

Puffinus tenuirostris

Two or three were seen as far south as about 26–27° N. on April 29. They were late

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individuals, as the early birds can be seen along northern Japan in late April.

Puffinus nativitatis

Small compact flocks and a few individuals were occasionally encountered south of about 27° N. and also around Marcus Island.

Pterodroma brevipes hypoleuca

Occasional individuals were seen sailing over the sea south of 27–29° N.

Diomedea nigripes

A few were always seen, sometimes floating on the water, and they followed the ship south to about 28° N., but none was observed to the southward. *D. immutabilis* was not seen; its occurrence in Japanese waters is earlier than *nigripes*.

Stercorarius pomarinus

Two birds were seen in Tokyo Bay on April 26, and a bird followed the ship for a while on April 28 at about 28° N.

Stercorarius longicaudus (?)

Three birds, probably of this species, were seen at a distance on April 27.

On arriving at Marcus early in the morning on April 30, *Sterna fuscata* and *Anous stolidus* were seen flying about the island but were never observed offshore.

GENERAL FEATURES OF MARCUS ISLAND

The island is situated over 1,000 miles from Tokyo, 600 miles S.E. by E. of the Bonin Islands (Chichijima) and 790 miles N.W. of Wake Island at 24°14′ N. and 154° E.,[2] in the same latitude as the north point of Formosa.

According to Yoshida, the former Japanese garrison (crew of "Kasagi") recorded a summer temperature of 87–88° F., rarely over 100° F. The colonists recorded over 130° F. outdoors, at the most 92–93° F. indoors, and in winter never lower than 60° F. Bryan, during a week's stay in August, noted a low of 72° F. and a high of 82° F. The spring temperature during our stay was as shown below:

Date	Temperature Maximum °C.	Minimum °C.
April 30	25.5	20.0
May 1	27.5	21.2
May 2	25.9	19.8
May 3	24.6	20.9
May 4	25.5	20.7
May 5	26.7	22.0

It was, however, very hot indoors, and the sunshine was strong and glaring against white coral gravel, the earth temperature reaching about 45–50° C. The brooding terns and noddies seemed to sit on their eggs to protect them from being overheated, as the eggs were cooler than the gravel. The weather was fine, and the only precipitation was on the night of May 2. Rainfall is rare, and, as fresh water is lacking, the drinking water is said to be obtained mainly during the rainy season in August.

The whole island is formed of coral gravel and is flat, being only a few meters above sea level. It has a triangular litoral line, a little over 4 miles in extent, the white beach being particularly extended at the western point. The coastal reefs are to be found along the northern and northeastern beaches, and the island is surrounded by scattered coral rocks about 200 meters offshore, especially on the northern coast. Formerly, the island must have had some elevated parts, as Bryan reports that "Near the north end the land attains a height of seventy-five feet which was the highest point found," and, "In the middle of the island along this side the highest point is not to exceed forty feet, while at the southeast point an elevation of sixty-five or seventy feet is attained." However, at present the whole island is almost entirely flat as the result of war destruction, and the central planted part is low, reminding us of former lagoons, which he mentioned. At these places he found "four separate deposits of loose black alluvial soil," which were a few feet deep according to Yoshida, but we found such soil to be entirely lacking at present, and there was no sign of

[2] Various other records have been made of its position. Cf. Bryan, 1903: 78–79; Yoshida, 1902: 674.

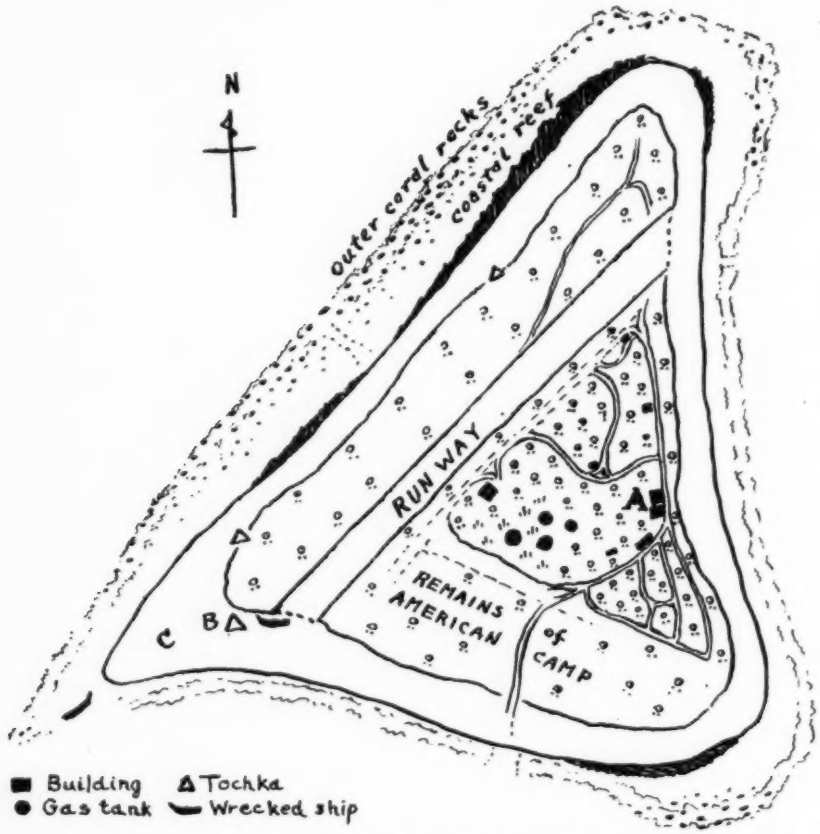

FIG. 1. Map of Marcus Island. A, weather station; B, a tochka on which noddies are breeding; C, main breeding place of the Sooty Tern, which also breeds on the outer coral rocks and flocks on the coastal reef.

the *Cocos nucifera*, which is said to have been thickly planted at these lagoons in an area of about three acres.

The central cover consists chiefly of *Messerschmidia argentea* ('Monpanoki'), a brushy plant, mixed with a few *Pisonia grandis* ('Togemi Udonoki'), with a dense creeping undergrowth of *Ipomoea Pes-caprae* ('Gunbaihirugao') and a few grasses. There were a few poorly grown papayas and five bananas, the latter having recently been brought from the Bonin Islands. It is interesting that Bryan reports no natural papaya, but states that he gave some seeds, together with those of several other plants, to the Japanese colonists to plant. Bananas were also introduced formerly, according to him, but have never fruited, and tobacco was then cultivated to be smoked by the colonists. Small land crabs, locusts, skinks, and geckos as well as Oedemeridae were particularly abundant, and we saw a dragonfly of *Sympetrum* type, said to be common in summer. We also obtained a young specimen of *Rattus rattus alexandrinus*, an unhealthy animal, found wild among the *Ipomoea*.

The above general features of the island, however, are now in a devastated state as the result of the recent war.

BRIEF HISTORY OF MARCUS ISLAND

It is said that an American priest discovered the island first, naming it Marcus, or Weeks, Island (whether Weeks is identical with Marcus is not clear). In November, 1883, Tsunetaro Shinzaki landed on the island as the first Japanese, coming on board the British ship "Eta" of the Yokohama Konshiro Company. Another Japanese, an offshore fisherman of Kinkazan (N. Honshu), reached the island accidentally. In 1889, Captain Rosehill of the United States visited the island and suggested its commercial value to his government, and in December, 1896, Shinroku Mizutani, the chief of the South Pacific section of the Tokyo Bird and Mammal Company, explored the island, followed by Haruzo Kobayashi, a former navy officer. They emigrated the natives of the Bonin Islands and Hachijo Island to Marcus, to engage in collecting feathers of the albatross which was then very abundant.

This trade was assisted by Shichigoro Kamitaki, a trader merchant of Yokohama, and the trade patent for bird-feather collecting, fishing, and salt production was given to Mizutani by the Tokyo Prefectural Government, which, on July 24, 1898, declared Marcus Island to be in the Bonin Islands section under the name Minami Torishima.

In July, 1902, a Japanese cruiser, "Kasagi," commanded by Lt. Akimoto, was dispatched to the island to receive the expedition party of Dr. Bryan of the Bishop Museum of Honolulu, who stayed on the island the week of July 30. On August 28 of the same year, another Japanese cruiser, "Takachiho," with Dr. Shinpo, Mr. Yoshida, newspapermen, a lawyer, and others on board, visited Marcus on a round-trip cruise from Yokosuka-Torishima-Marcus-Bonin Islands.

Both Bryan and Yoshida reported on the history, geology, climate, fauna, and flora, and the more scientific and detailed report by Bryan is of particular importance in ornithology. As curator of ornithology at the Bernice P. Bishop Museum, he gives valuable data on the bird life of the island, reporting many species which are not found on the island now, including *Micranous marcusi*, which he described as a new species. Yoshida, a geologist, only reports some birds in vernacular names used on the island. According to him, there were 29 colonists (including four women) making their living by catching the birds which they stuffed for exportation. The birds, about 20 species in all, were all sea birds crowding all over the island and were exceedingly tame. They were caught with a bamboo pole with a round net at the end and were stuffed in fast procedure. This regrettable slaughter, chiefly of *Sterna fuscata*, which was the most numerous species, is further described in detail in Bryan's report. Most regrettable is the fact that the albatrosses, *Diomedea immutabilis* and *D. nigripes*, for whose feathers the colonists first settled on this island, were already all gone by that time. The sad history of their disappearance is also recorded in detail in his report.

PRESENT CONDITION OF THE ISLAND

Until how recently the colonization existed is not certain. However, World War II was undoubtedly the second and decisive crisis for many species of birds, as the physical topography was entirely changed. About 5,000 Japanese troops were garrisoned on the island, and after severe bombardment by United States planes they retreated from the island before the end of the war to be replaced by American troops. The newly constructed camps and materiel of the latter were then all destroyed (a few trucks and jeeps have been repaired and are now in use on the island) by a violent typhoon, accompanied by storm waves which washed out almost one third of the island. (Bryan reports typhoons of particular violence in October, 1901, and September, 1902.) Subsequently, a weather station was constructed on the eastern coast by the Japanese under the supervision of American occupation forces (construction was begun in December, 1950). About 30

persons are now working at this station, supplied every 3 months with foods and materials from the Tokyo Central Weather Station.

Now being totally disfigured, Marcus Island, which lies peacefully and beautifully with green cover and white beach surrounded by deep-colored semitropical ocean, impressed us as a disappointment as soon as we landed on it. Everywhere on the island are to be found residues of war. All along the coast are trenches, with tochkas here and there on which rusted anti-aircraft guns are still pointing to the sky. On the northern coast, from the eastern end to the western, a broad runway was constructed for occasional visits of airplanes, and almost all the southwesterly one third of the island is left as it was devastated by the typhoon, the ruins of United States camps and trucks scattered everywhere. Thus, the brushy jungle which formerly occupied four fifths of the island (*fide* Yoshida) is now restricted to a small central section through which roads pass and which in many places is dug up for air-raid shelters, while ruined, rusty gas tanks are conspicuous among the green cover.

Under such circumstances, with continuous human intervention, many sea birds which formerly bred abundantly on this island have disappeared completely. The burrow-nesting shearwaters (*Puffinus pacificus*) lost their breeding place in the soily regions, and the ground and tree nesters such as *Puffinus nativitatis*, Frigate Bird, Tropic Bird, and Boobies as well as the beautiful Fairy Tern have abandoned the island. The island, formerly crowded by these birds, is now nothing but a ruined coral elevation. In fact, Bryan reports (August) 18 species of sea birds, including migrant waders, of which 9 species were breeding, and he secured 56 specimens without using a shotgun (the use of a shotgun is said to have been prohibited by the Japanese cruise officer).

On my recent trip (early May) I found but eight species, of which only two, *Sterna fuscata* and *Anous stolidus*, were breeding. The length of both Bryan's trip and mine was a week, and, although my visit was seasonally earlier, I was told by the workmen of the station that none of the other species come to breed in the summer.

The Sooty Tern (*Sterna fuscata*), which I estimated at about 1,000, should have been at least several times as many formerly. They are unfortunate survivors, because, to my regret, their breeding is still being disturbed. Their whole flock was gathering at the western beach when I landed on April 30, but it was a surprise that only three eggs were found left and few females were about to lay eggs. At this beach many eggs were said to have been taken until just a few days prior to our visit. Two days after, I noticed that the whole flock had given up this beach, scattering to the outer coral rocks of the northern side where wading is necessary to reach the eggs. They seemed to have soon laid eggs at these new, safer places, and this habit has apparently retained their present number. However, if this condition continues, their future decrease to the point of extinction on Marcus is quite certain, and, therefore, I hope that my friends on this remote island will pay attention to the future of their birds.

The noddy (*Anous stolidus*), on the other hand, is a species that has found new egg-laying places on war remnants which are safer than their former favorite sites on the trees, as reported by Bryan, where the eggs were likely to be disturbed by people. A few of them still breed on the coral rocks with the Sooty Terns, but they now breed principally in small colonies on abandoned gas tanks, tochkas, and the like, and even high up on the wireless towers. All these colonies are, therefore, inaccessible, or at least hard to reach, and, though their number is only about 200 in all, this species may increase in the future until these few safe places become crowded. However, compared with the former population their decrease is evident.

Only a few other species of birds were found on the island. Two *Gygis alba* were seen and

obtained, but they were nonbreeding individuals as both were females with small ovaries; none of the *Anous minutus marcusi* originally described from this island by Bryan was found. About 20 Golden Plovers were the only familiar birds living on the ground, and five American Wandering Tattlers were staying on the coastal reef on the northern side. A Turnstone and a Whimbrel showed up for a 1-day rest on their migration, and a Great Skua (probably) was unexpectedly seen.

According to the station workmen the island is only occasionally visited by the Frigate Bird, and recently an *Ardea purprea* (probably) and three white Egrets were obtained or noted on the island as stragglers.

ANNOTATED LIST OF BIRDS

Although the island was formerly crowded with sea birds, the species known from this island are very few, 32 so far recorded. Situated out in the ocean apart from other islands, Marcus seems to be visited by only a few of the migrant shore birds in very small numbers, but casual migrants or stragglers will be added in the future. Land birds are entirely lacking, and this might be correlated with the history of the formation of the island. It was surprising that we found skinks and ground insects, including ants, on this small coral island. That land birds can not thrive on this island is easily explained by the lack of fresh water and foods such as fruits and a variety of insects, spiders, or earthworms. Moreover, the only trees are two kinds of small, tropical, brushy ones, and, though they make a rather thick jungle, it is too simple a cover without any big trees which will offer a good, cool shelter for arboreal birds.

FIG. 2. Rusty gas tanks on which noddies are breeding. Photograph by author.

Bryan reported 18 species mostly collected by himself, and there are a few species to be added to his list based on specimens formerly preserved in the Tokyo University and in the Matsudaira, Kuroda, Sr., or Takatsukasa Collection, some of which are now deposited in the Yamashina Museum but others were destroyed during the war. These specimens were mostly obtained from stuffed-skin dealers in Tokyo. On the present trip the only species new to the list were sight records of *Numenius phaeopus variegatus* and *Catharacta skua* (not definite) and the herons of which I was told by the station workmen.

The list of known species are as follows:

1. **Fregata minor minor** (Gmelin)

   Bryan reports, under the name *Fregata aquila*, a full note on nest and chicks and mentions how it attacks the boobies. There are three specimens, in the Yamashina Museum, one adult and two juveniles obtained in 1911, and there were six more specimens (1911 and June, 1910) in the Kuroda and Takatsukasa collections (all destroyed). A bird is said to have appeared in May, 1951, and late April, 1952.

2. **Sula leucogaster plotus** (Forster)

   Bryan observed only a few individuals on the rocks but saw a young bird which had been captured and kept alive by the colonists. He reports this gannet under the name *S. cyanops*.

3. **Sula sula rubripes** Gould

   Thousands were breeding in August when Bryan visited the island. A detailed field note on eggs and chicks is given by him.

4. **Sula dactylatra personata** Gould

   Under the name *Sula piscator*, Bryan reports a few observed specimens of this

booby and one specimen given to him by colonists.

5. **Phaëthon rubricaudus rothschildi** (Mathews)

Bryan reports in detail on its breeding, eggs, and chicks but mentions that it was already decreasing at that time. Two specimens are now in the Yamashina Museum, one a former Tokyo University specimen, September, 1902, and the other from the Bernice P. Bishop Museum, August 5, 1902.

6. **Phaëthon lepturus dorotheae** Mathews

No record is found in literature except in the *Hand-List of the Japanese Birds* (1922, 1932, 1942). The source has apparently been the specimen in the former Kuroda or Takatsukasa Collection, now destroyed.

7. **Oceanodroma furcata furcata** (Gmelin)

Also reported only in the Japanese hand-list, 1932 and 1942.

8. **Puffinus pacificus chlororhynchus** ('**cuneatus**') Lesson

Bryan found this species nesting in burrows at soily places, and many were seen by him resting under bushes or logs. Eggs and chicks are also reported.

9. **Puffinus nativitatis** Streets

Young of all stages are reported by Bryan, who found this species under bushes or roots, together with *P. pacificus* and tropic birds, but never in burrows. There is one specimen, dated November, 1913, in the Yamashina Museum (former Matsudaira Collection).

10. **Pterodroma (?brevipes) hypoleuca** (Salvin)

[For specific name cf. Austin, Jr., 1952: 393.]

Not reported by Bryan, but in the Yamashina Museum (former Matsudaira Collection) there is one specimen obtained in October, 1908.

11. **Bulweria bulweri bulweri** (Jardine and Selby)

Only recorded in the Japanese hand-list, 1932, 1942.

12. **Diomedea immutabilis** Rothschild

Only one was seen and another was secured by Bryan, who reports the former abundance and slaughter by colonists.

13. **Diomedea nigripes** Audubon

None of this species was seen or secured by Bryan, but he reports that he was told that it was as abundant as the above species.

14. **Tringa incana incana** (Gmelin)

Few of this subspecies probably visit Marcus Island regularly. Bryan observed several birds in August and secured a specimen from the colonists. I saw five birds during my stay, obtaining one bird on May 1.

15. **Calidris ferruginea** (Pontoppidan)

Only recorded in the Japanese hand-list, 1922, 1932, 1942.

16. **Pluvialis dominicus fulvus** (Gmelin)

This species is a familiar plover on Marcus and is said to be seen in almost any season. About 20 were on the island, and I obtained two samples on April 30 and May 5. They were seen all the time on the hot surface of the runway or on the roads through the jungle, only appearing on the beach to bathe and drink water. Bryan observed a flock of 11 birds on August 4.

17. **Thalasseus bergi cristatus** (Stephens)

Only recorded in the Japanese hand-list, 1922, 1932, 1942.

18. **Sterna hirundo longipennis** Nordmann

Only recorded in the Japanese hand-list, 1932, 1942.

19. **Sterna lunata** Peale

There are seven specimens (dated October, 1910) in the Yamashina Museum (former Matsudaira Collection) and one in the Game Management Bureau, Tokyo, with the same date.

FIG. 3. A pair of noddies on a broken tochka near the shore. An egg lies below them. They are also breeding, in company with Sooty Terns, on the rocks in the background. Photograph by author.

20. Sterna anaethetus anaethetus Scopoli

Only recorded in the Japanese handlist, 1922, 1932, 1942.

21. Sterna fuscata oahuensis Bloxam

Bryan reports this tern as by far the most abundant bird and mentions its slaughter by the colonists. During March to September alone not less than 50,000 birds are said to have been killed. A specimen dated September, 1903, is in the Yamashina Museum (former Tokyo University Collection), and I secured eight birds and three eggs. The Marcus specimens are larger than those of the Bonin Islands, Palau Island, or Riukiu Islands.

About 1,000 were breeding on the beach and coral rocks. They are said to have arrived about a week before our visit on April 30. The female lays a single egg. No chicks were seen. In the early morning they were scattered around the island and gathered in a flock on the beach or coral reef. All day long, almost always in pairs, they were flying high and low, sometimes soaring at a great height, over the island to and from the coastal breeding place. Their white underparts and underwing coverts are quite beautiful when seen from below against the background of deep blue sky. Toward the evening and at night they were particularly noisy around the colony. When the colony is intruded upon, they crowded noisily over the intruder with harsh cries, almost attacking his head, and always from behind. Once a flock was observed fishing a little offshore on the northeast side of the island where squid (and, con-

sequently, big fishes) are abundant. All the birds obtained, including also *Anous* and *Gygis*, had small squid in their proventriculus. They never seemed to go far from the island.

22. Procersterna cerulea saxatilis Fisher

Only one specimen (purchased in Tokyo) obtained in August, 1911, was in the former Kuroda, Sr., Collection.

23. Anous stolidus pileatus (Scopoli)

This noddy was found by Bryan breeding in good numbers preferably on trees, and all stages of the young were seen in his visit in August. I found about 200 birds breeding in separate colonies on ruined gas tanks (four in number, about 10 pairs on each), a small wooden tank, and an abandoned tochka, and a few birds high up on the top of the wireless tower. A few isolated pairs were nesting on the beach and coral rocks. Seven examples and four eggs were obtained.

Their flight is different from that of the Sooty Tern (slower wing beats), and their edged, pointed wings often looked like those of a falcon; their large tails are very characteristic. They often skim near the water surface which they touch with their bills, probably to drink. A pair was often observed to make a rapid circling flight, almost touching each other, with very rapid flapping, then to rise higher and higher into the sky. This is apparently a kind of pleasure or courtship flight. Pair after pair were flying rather low over the island between the colony and the coast and were often observed picking up nest materials—small sticks, dried grasses, etc.—from the ground while fluttering their wings. At their colonies they sat closely on the eggs, and now and then the whole group took wing to circle around the colony for a while and then settle again. A few were seen at a great height on the wireless tower, sitting and bringing back nest materials, and flying until after dark. Their voice is quite characteristic, rather resembling that of a crow though much weaker, and they make two sounds—a call note of one syllable and an alarm note, translated by Bryan as K-r-uk, K-r-u-k. These voices, heard in hot atmosphere, are very impressive.

Anous differs from *Sterna* in various respects besides external characters and voice. The body fat and yolk of the egg are yellow instead of orange as in *Sterna fuscata;* the sternum, which is double notched posteriorly in *Sterna*, is single notched in *Anous;* the syrinx, correlated with the characteristic voice, is peculiarly provided with a gelatinous cover; and the caeca are long, not being the small attachment usual in the gulls and terns.

24. Anous minutus marcusi (Bryan)

The original description is given in Bryan's report based on two adults and fledged young. He reports that this species was much less abundant than the previous one. The Yamashina Museum has two specimens obtained in 1910 (former Tokyo University Collection), and another is in the Game Management Bureau Collection, dated December 4, 1908. None of this species was found during my visit.

25. Gygis alba candida (Gmelin)

Bryan reports this species as quite common, breeding in jungles, and he observed many grown chicks. Now it apparently does not breed, for the only birds seen, which were obtained, were two females with reduced ovaries. They were flying over the wooded parts and resting in *Messerschmidia*. The basal half of the bill is a beautiful cobalt blue, the rest being bright black; the iris is almost black; the feet are bluish white with creamy white webs and black claws; and the skin is grayish black.

There are two specimens in the Yamashina Museum, dated September, 1902 (Tokyo University Collection), and No-

vember, 1910 (Matsudaira Collection), and another example with the latter date is in the Game Management Bureau Collection.

26. **Larus argentatus vegae** Palmèn

A March specimen was given to Bryan by the colonists, who are said to have reported to him that it had been obtained four times previously in the winter season. He was told also that another species of gull had sometimes occurred.

The following are sight records.

27. **Numenius phaeopus variegatus** (Scopoli)

I observed one bird on May 6.

28. **Calidris acuminata** (Horsfield)

Bryan reports a single example observed on August 6.

29. **Arenaria interpres interpres** (Linné)

Bryan observed a flock of 11 birds on August 4, and I saw a bird on May 1.

30. **?Catharacta skua**

One bird was observed from a distance in the early morning of May 3 (after rain) at a pool remaining on the runway. It was preening its feathers and flew off soon so that I could not see it, but Mr. Sakagami saw the white part on its wings.

In addition to the above, the following two species are to be added, of which I was told by the weather station workers.

31. **?Ardea purpurea**

A bird was caught in mid-April, 1952. It was in an exhausted state and was finally caught by hand, apparently a straggler.

32. **Egretta** sp.

Three white egrets stayed on the island during the summer of 1951 and disappeared after a typhoon.

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Some Aspects of the Biology of the Aku, *Katsuwonus pelamis,* in the Hawaiian Islands

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THE AKU, *Katsuwonus pelamis* (Linné), is the most important species of fish taken commercially in Hawaii. It supports the only Hawaiian fishery which supplies a product, canned tuna, for export as well as for local consumption. It is, on the one hand, a species that affords the greatest promise for expansion of the Hawaiian fishing industry and, on the other, one of which little or nothing of the life history or biology is known.

Hence, the scientific staff of the Division of Fish and Game of the Territory of Hawaii, following an initial study of the length frequencies of Hawaiian aku by Bonham (1946), has been engaged in several projects concerned with the biology of this fish. Included among these projects are further studies of length frequencies, studies of the span and character of the spawning season, of the nature of schooling, and of the conduct of the fishery with a view toward establishing a basis for obtaining a fairly accurate measure of catch per unit of effort. The present paper is concerned with all these projects except the last.

Beginning in the late summer of 1946, aku obtained from the commercial landings were sexed and the length measured. The technique of sexing will be described later; the measurement of length obtained was from the tip of the snout to the end of the mid-caudal rays. This measurement was taken by means of calipers similar to those described by Marr and Schaefer (1949). In part, measurements made during 1950 and later were taken by marking the length on a celluloid strip by punching a hole in it. The lengths obtained are, for the same fish, very slightly less than the lengths obtained by the use of calipers. During the winter off-season period, both the number of fish measured in a sample and the number of samples obtained were affected by the availability of fish at the cannery; however, the frequency of sampling was chiefly affected. The number of fish entering into each of the percentage frequency curves plotted in Figure 1 is shown in Table 1. As individual samples usually represented some 100 fish, and sometimes much less, it is obvious that most of the percentage frequency curves of Figure 1 are composed of a number of samples combined together.

In the beginning of the program, estimates of the degree of maturity of the fish sampled were made by noting the appearance of the gonads; however, these estimates did not provide a measure of sufficient accuracy to show adequately the spawning season of this species. For this reason, beginning with the summer of 1948, ovaries were removed from 20 of the fish in each sample and preserved in formalin, and subsequently each ovary was drained and weighed to the nearest tenth of a gram. From each, 50 ova chosen at random were measured to the nearest one hundredth of a millimeter by means of an ocular micrometer in a compound microscope.

Beginning with the summer of 1949, a large part of the samples taken for length measurements were taken aboard the aku fishing vessels while landing the catch. These sam-

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TABLE 1
YEAR-CLASS MODAL LENGTHS IN CENTIMETERS AT VARIOUS MEAN DATES

MEAN SAMPLING DATES	YEAR-CLASSES (DATED BY PRESUMED YEAR OF ORIGIN)								NUMBER OF FISH MEASURED
	1943	1944	1945	1946	1947	1948	1949	1950	
Sept. 15, 1946	80.36	74.40	43.74						2,311
Dec. 8, 1946	81.46	75.96	51.95						3,463
July 3, 1947		79.30	68.10	43.96					5,364
Feb. 25, 1948			78.00	61.88					429
June 28, 1948			79.74	71.79	43.79				3,136
Dec. 8, 1948			80.00	74.64	57.68				160
Aug. 16, 1949				79.50	71.89	46.20			588
Dec. 26, 1949					73.84	53.78			853
July 12, 1950						71.91	44.08		4,878
Dec. 24, 1950						74.21	53.59		1,266
July 4, 1951							68.13	44.21	8,409
Total									30,827

ples were taken from such portions of the catch as, according to the captain of the vessel making the landing, had come from a single school of fish.

Acknowledgments

The field work for these studies was done by the employees of the Division of Fish and Game who deserve much of the credit for the results. Mr. W. Van Campen and Mr. J. P. Welsh took a large share of the length measurements. Mr. T. Shimizu took those length measurements from single school samples for 1949, 1950, and 1951, and Mr. F. W. Loo, statistician for the Division of Fish and Game, contributed to the statistical analysis herein. Dr. A. L. Tester of the University of Hawaii has offered a number of constructive suggestions. The fishermen, boat owners, and others engaged in the aku fishery have been most helpful. The officials of Hawaiian Tuna Packers, Ltd., have been, at all times, cooperative and interested in the program.

AKU LENGTH FREQUENCIES

The length measurements are plotted in Figure 1 and are grouped into units covering, for each length frequency curve, approximately a 6-month period. This grouping was selected for two reasons: (1) To insure the inclusion of an adequate number of measurements in each group, and (2) to make it convenient to plot, with the first consideration in mind, the length frequencies on an approximately uniform time scale. Some indications of the factors which made it seem best to place the length data in a few comparatively large groups will be given later.

The length data, as plotted in Figure 1, have a feature of considerable interest—the apparent progression of modal groups through the fishery with time. Such a group entering the fishery during the summer months at a modal length of 40 to 50 centimeters may be identified with a modal group of 55 to 60 centimeters which appears in the winter fishery, and in turn with a modal group of 68 to 72 centimeters which occurs in the following summer months' catch. There is an additional group at a modal length of 79 to 80 centimeters sometimes represented in the summer landings which may represent a group of fish a year older.

If it is assumed that these modal groups represent year-classes, the following interpre-

tation of the length frequency data may be made:

At some age, perhaps one or two years, an age group or year-class is first taken in significant amounts by the fishermen during the summer fishing. By the second summer, this age group, at a length of 70 to 75 centimeters, is again taken and, as a matter of fact, is the size group most eagerly sought by the fishermen. This year-class appears again in the catch during the third summer but cannot be traced thereafter with any certainty from the available data.

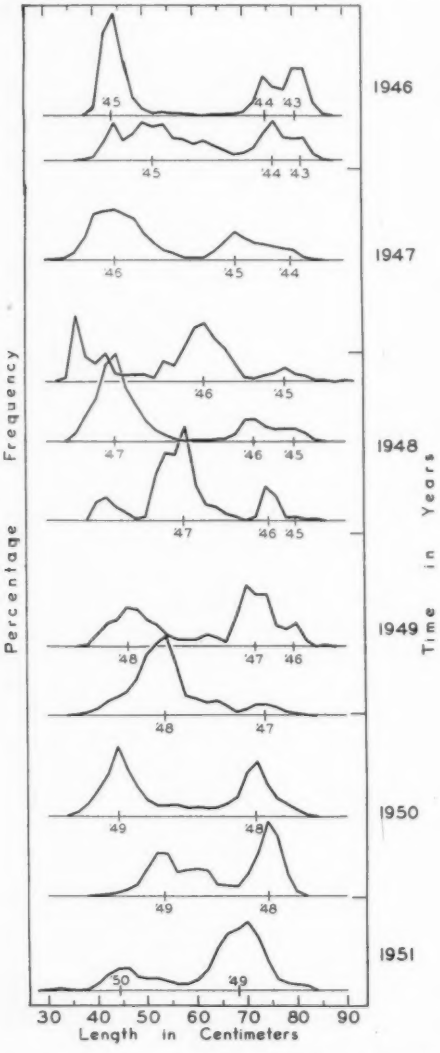

FIG. 1. Length frequencies of Hawaiian aku, 1946–51. The number identifying modal positions is the presumed year of origin of the modal group.

The age of the modal group of smallest length, that of the youngest year-class fished, is of interest. It would appear to be possible to form some judgment of this age by fitting the observed modal length to a growth curve and extending the growth curve toward the origin. It is appreciated that the initial growth period, during the larval stages, will probably not be described by a simple growth curve adequate for the later period of growth; hence, this approach would not, of course, yield a certain answer, but it may, at least, give a likely estimate of the age of the fish. A growth curve of the type described by Walford (1946) was fitted to the length frequency data in the following manner: The obvious modes were selected (see Fig. 1) and the three highest classes for each mode were averaged. This average was thereafter taken as the modal length (these modal values are shown in part in Table 1). Then the modal lengths as obtained from the summer samples were paired with the modes presumed to be the same of a year later.

This relationship between length at age N and at age N + 1 which may be taken as a year or any other equal time interval later, as shown by Walford (1946), is usually a linear one. It was assumed to be linear for these data, and the line of best fit was computed by the method of least squares for the following paired values: Length at age N and N + 1, at age N + 1 and N + 2, and at age N + 2 and N + 3, if available. The equation of this line would permit, of course, the computation of the length at N + 1, given the length at N, or the length at N + 2, given the length at N + 1.

The average of all the mean sampling dates for the summer for the period of September

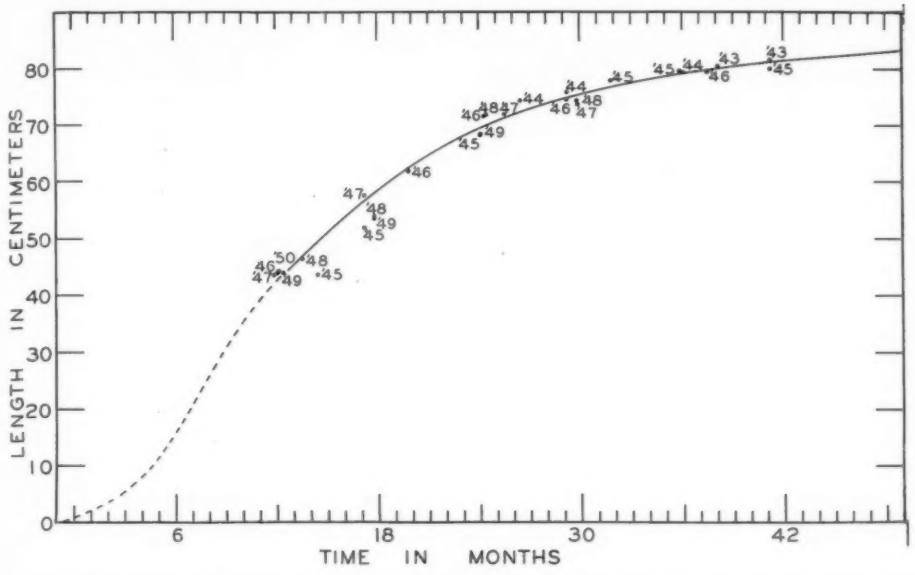

FIG. 2. Growth curve of Hawaiian aku. The number identifying modal lengths is the presumed year of origin of the modal group.

15, 1946, to July 4, 1951, was calculated, as well as the average of all the modal lengths of the modal group composed of fish of the smallest size, for these same sampling dates. This average modal value was taken as length at age N, which was assumed to be 1 year, and the growth curve shown in Figure 2 was computed, using the equation for the least square fit obtained as described above. Shown also on Figure 2 are the various modal values from Table 1 for which the computed growth curve would seem to provide a good fit.

The modal values obtained during the winter period were not used in the computation of the growth curve, as the mean sampling dates were usually much less than 6 months later than the mean sampling dates for summer, and, in addition, the number of fish represented by the winter samples was often small. Again the mode of smallest-size fish occurring in the winter samples was not included in Table 1, as it was felt that fish of these sizes or a little less were discriminated against by the fishermen and that these modal groups sampled during the winter represented, therefore, an incomplete part of the entering year-class. This judgment is, perhaps, strengthened by the fact that these particular modes do not seem to fit into the same pattern as the others. By summer the entering year-class would seem to be adequately represented in the catch in that the modal positions found for it do fit into the pattern of modal lengths of the older fish.

MODAL LENGTH AND AGE

If the age of the year-class entering the fishery during the summer is assumed to be 1 year, even though the growth attained during the first year seems high, it fits the pattern of growth which follows better than the assumption of some other age, such as 2 or 3 years, which may otherwise seem likely. If the judgment made here of the age of the fish in the entering year-class is in error by a year or more, then the initial accelerating portion

of the growth curve would seem to persist for a year or more. It would be difficult to obtain an acceptable fit of a growth curve to these modes on any other basis. However, lacking data regarding the nature of the initial accelerating portion of the growth curve, the possibility that the entering year-class is more than 1 year old, even though deemed unlikely, cannot be disproved.

This interpretation of the length data would imply that the aku landed in Hawaii is a short-lived, rapidly growing fish and that the fishery depends on aku belonging largely to two adjacent year-classes and entirely to three. This interpretation is not proved here but is offered as a plausible hypothesis to account for some of the features of the length frequency data given in Figure 1. The most direct method of testing this hypothesis would seem to be by the tagging and recovery of fish of known size, as there is as yet no reliable means of age determination for this species. However, the albacore fishery of western North America also apparently draws its catch from a stock composed of but a few year-classes, as described by Brock (1944).

The appearance of distinct modal groups in these length frequencies, if due to year-classes, is somewhat surprising when the apparent rapid growth rate is considered together with the long spawning period, the evidence for which will be discussed later. The period of active spawning is perhaps much shorter than the occurrence in the landings of fish with fairly large ova would indicate. It is also possible that, although the period of spawning may be of considerable duration, only the fish which hatch during a limited part of that period survive in significant numbers.

LENGTH SEGREGATION IN SCHOOLS

As previously mentioned, beginning in the summer of 1949 a series of samples were taken in such a manner that each represented fish captured from a single school. This was practical inasmuch as only a single school would ordinarily be chummed up by live bait and fished at one time. This catch would often be stored by itself in an empty bait well. The fish were sampled aboard the vessel when it reached port, and samples were taken from those bait wells which, according to the captain, contained fish caught from a single school.

The "pure school" samples obtained during the summer of 1949 proved of sufficient interest to justify an increase in this sampling program. Between May 16 and September 30, 1950, some 120 samples with, on the average, 34 fish measured in each were obtained. As these length data for 1950 were more adequate and did not differ in the features of interest mentioned here from those for 1949, the 1950 data will be discussed. The 1951 data were, in all aspects considered here, also similar to the 1950 data.

The most striking feature of these samples is the comparatively small range of the length of fish within them which is in contrast to the range of the length of fish in the landings as a whole. For example, the mean range in length for the pure school samples was 11.3 centimeters, the least range 5 centimeters, and the greatest 21 centimeters. In contrast to these small ranges, the range of the seasonal summary of length measurements for the same period is 47 centimeters. It would appear that the school is a highly size-selected group in which those causes that select for size may well obscure the pattern of size distribution in the population as a whole. Hence, measuring a larger number of fish from a few schools would not reliably reveal the pattern of size distribution of the fishable stock; fish taken from a large number of schools must be measured. The fact that aku appear to school by size must, of course, be considered in the design of any program to obtain length samples. Although the effect may be less extreme, it may be suspected that schooling by size occurs in other tuna populations and species.

The causes of the observed size segregation by schools is a matter of interest, but they are not clearly evident from an examination

of the length data. Of the various possible causes that may be advanced, the most probable one, in my opinion, is that the effect is a mechanical one dependent upon the fact that speed through water is, among other things, a function of size.[2] The cause of the relatively great similarity in the sizes of fish within a school also might be the result of fish of similar age and size remaining in a school together more or less permanently. It is likely that members of such a permanent school would resemble one another more nearly in growth rates than they would resemble members of other schools even though the ages were the same, since environmental differences would effect the school as a unit.

If association of fish by length within a school is dependent upon a real difference in the top speed attainable by fish of different size, then other events must necessarily occur for this effect to express itself in the manner described here. There must be a schooling instinct or reflex which impels the fish to school. (Of the nature of its mechanism or function nothing will be discussed here, but the assumption of its existence is fundamental to the argument.) The fish must spend some of the time swimming at or near top speed or at an optimum speed differing for each size of fish which in turn should result in fish of like sizes schooling together and apart from fish of unlike sizes. This hypothesis would not be incompatible with fish of various ages but similar sizes occurring together or with the occurrence of schools of mixed sizes; the mechanism of size segregation could be effective intermittently, depending on the frequency of sustained rapid swimming by the fish. If the explanation is correct, then schools of fish of mixed sizes may occur. The fact that the range of lengths for fish sampled from presumably pure schools is somewhat variable would strengthen the likelihood that some pure schools of mixed sizes do occur. If, on the other hand, occurrence of fish of much the same size together in a school is due to the relatively great stability and duration of such schools, then the occurrence of mixed sizes of fish in pure school samples in any number would not be expected. If mixed sizes of fish do occur in the pure school samples, the variance of those samples should not be homogeneous. Bartlett's test of the homogeneity of the variance was computed from the length frequency data for both the pure school samples measured in 1950 and 1951 (Snedecor, 1948: 251–252), and the probability that the variances were homogeneous was found to be less than .001 for both years. Hence, of the two explanations for the observed size segregation in schools, the hypothesis that the effect is due to a speed differential in fish of different sizes would seem to accord best with the nonhomogeneity of the variance of these samples. However, the above analysis is not conclusive, and it cannot be denied that other explanations as well are possible.

[2] Designated by Sir Isaac Newton as the *Principle of Similitude*. As applied to ships, it may be stated that the speed of a model and of its full-size counterpart should be proportional to the square roots of their dimensions. The dimension usually taken is the length, and the ratio $\frac{S}{\sqrt{L}}$ is employed in naval architecture to convert the speed observed for a model to that expected for the full-size counterpart, where S equals speed and L length.

SPAWNING SEASON

The program initiated in 1948 of weighing an ovary from each of the first 20 female fish of a sample and then measuring the diameters of some 50 ova from it was preceded by routine subjective observations on the degree of maturity for those samples sexed and measured during 1946 and 1947. However, these observations did not indicate the existence of a definite spawning cycle, possibly because the period of observation was insufficient.

In immature fish the gonads appear as two slender strips lying along the dorsal part of the visceral cavity. It is difficult or impossible to sex them by a gross examination of the gonads. As the fish mature, the gonads increase greatly in size and come to fill most

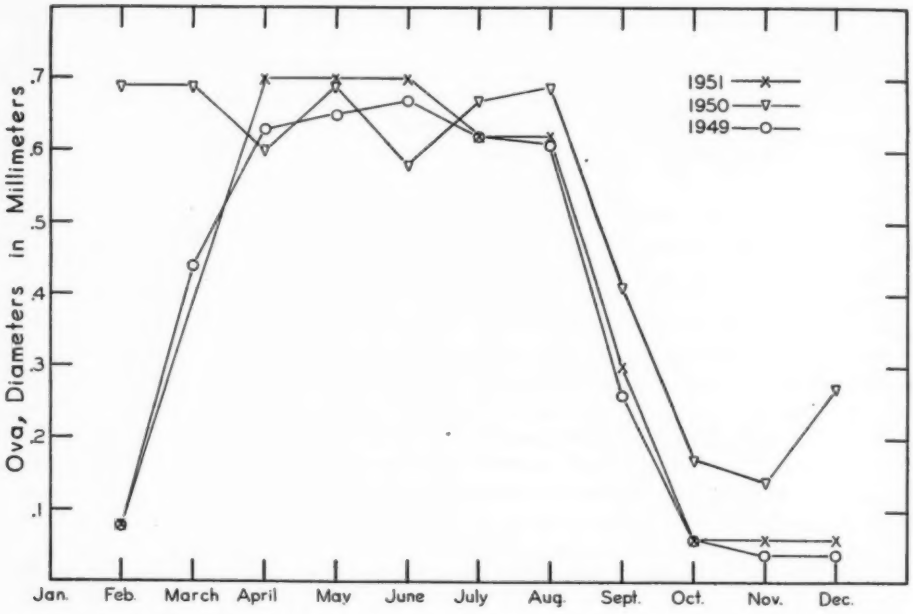

FIG. 3. Average modal diameter of the largest group of ova present in ovary samples for 1949, 1950, and 1951

of the space lateral to the visceral mass. The ovaries become bright yellow, deepening almost to orange in very mature specimens. The small eggs can be seen clearly through the ovarian membranes, and the small blood vessels become increasingly prominent in such fish. The testes of mature males are smooth in texture, pure white, and of more fragile texture than the ovaries. The sex of a mature or maturing fish is easily determined by a gross examination of the gonads.

The ovaries of spawned-out females usually appear large but flabby and empty, are often dark and somewhat bloody, and contain a few large disintegrating ova.

Fully ripe fish were very rare in the landings; such fish are apparently not commonly available to the fishery. One fish 43.2 centimeters long, examined on June 20, 1947, appeared to be fully mature. When it was opened, a gelatinous mass of eggs came foaming out of the visceral cavity in sufficient quantity to make a fair double handful. These eggs, assumed to be mature, were the largest seen in quantity in any of the gonads observed, averaging about 1.125 millimeters in diameter. They were smooth and round (or slightly oval) and contained a single yellow oil globule which varied from 0.22 to 0.45 millimeter in diameter. In contrast, the larger ova from maturing aku as taken by the commercial fishery measure only from 0.4 to 0.9 millimeter in diameter and have a cluster of two or three oil globules.

The beginning of the spawning season was not observed in 1948, as the program of taking ova diameters and ovary weights revealed that the fish sampled at the beginning were as mature as ordinarily are available to the fishery. From the beginning of the program, June 16, 1948, until the middle part of September, spawned-out fish were also very rare; after that time they dominated the catch.

However, the spawning season studies did

begin early enough in subsequent years to span the entire spawning season, with the possible exception of 1950; hence, the analysis of the data for those seasons will be presented. However, the study of the data for the 1948 season gave equivalent results for the short period covered.

Given in Figure 3 are the mean of the ova diameters measured, averaged for each month for 1949, 1950, and 1951. Large ova first appear in late February, March, or April and are found until September. During the remainder of the year the ova are small. Presumably, eggs are maturing between March and September but not during the other months of the year. Not until after the presumed end of the spawning season in September are fish with flabby, empty ovaries encountered. During the summer when the ovaries attain their greatest growth, spawned-out fish are evidently not available to the fishery. The spawning season, as indicated by Figure 3, is a long one, and aside from its length there are a number of other characteristics which may guide some guesses regarding its important features. These are: (1) The great rarity of fish containing fully matured eggs in the commercial fishery; (2) the lack of fish with ovaries sampled within the spawning season which present the spawned-out appearance to be observed in those fish ovaries sampled after mid-September; (3) the apparent absence of a trend in mean ova diameters during the spawning season which is shown in Figure 3; and (4) the multimodal frequency distribution of ova diameters during the spawning season, as shown in Figure 4, in which the diameters of 1,000 ova measured from a single ovary are plotted. At other times, aside from a few large eggs being resorbed immediately following the spawning season, only a single modal diameter of ova is in evidence, and this is quite small—less than 0.1 millimeter.

Assembling these observations into a partern is not difficult; however, there are admittedly other patterns possible. The multi-

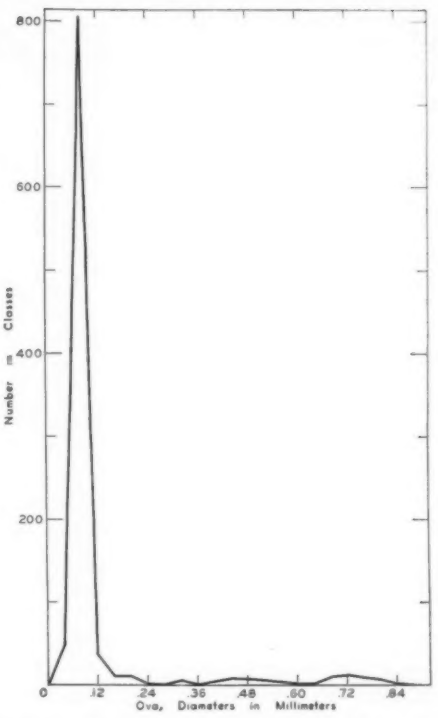

FIG. 4. Size frequency of ova taken from a single ovary, summer of 1949.

modal distribution of ova diameters during the spawning season and its absence at other times would infer that individual fish spawn several times. This inference is strengthened by the absence of an over-all trend in ova diameters during the spawning season (that is, the dominate diameters do not progressively increase or decrease) and perhaps also by the absence of fish that are obviously spawned-out until after the end of the spawning season.

Table 2 gives the relative proportion in the samples of ova diameters of certain sizes. Although fish with ova approaching 0.7 or 0.8 millimeter in diameter were quite rare, fully mature ova are over 1 millimeter in diameter. This may imply that fish with ova diameters of 0.7 millimeter and above become

TABLE 2
COMPARATIVE ABUNDANCE OF OVA MODAL GROUPS OF VARIOUS DIAMETERS IN THE SAMPLES TAKEN FOR THE SUMMER OF 1949

MODAL DIAMETER OF THE GROUP OF LARGEST OVA FOUND	PERCENTAGE OCCURRENCE OF OVARIES WITH SUCH OVA GROUPS IN THE SAMPLES
Millimeters	
0.48	5
0.60	30
0.68	55
0.80	6
0.88	4

progressively less available to the fishermen until a short time after spawning and that when they again enter the catch the dominate ova diameters in their gonads are 0.4 to 0.5 millimeter. In turn, these ova may grow and mature and the spawning cycle repeat itself. Inasmuch as the data do not include information concerning the histories of individual fish but represent a statistical cross section of the ovarian situation at various irregular stages for various fishes, it is difficult to obtain a valid basis for judging the rates of growth of ova and the number of times fish may spawn. If the spawning act was a periodic matter, occurring at the same time for all fish, it would be possible to judge when it occurred and how often; however, if it occurs irregularly with relatively small groups of fish spawning together as the ova mature, data of the nature obtained during the present study cannot adequately describe the situation.

SIZE OF FISH AT MATURITY

The smallest fish that possessed maturing ova during the spawning season were around 40 to 45 centimeters long. Fish 35 to 40 centimeters in length had ovaries that, with a few exceptions, seemed immature. Immature fish are rare in the commercial landings during the spawning season, as are likewise fish less than 40 centimeters in length. It therefore appears likely, considering also the information on age and rate of growth, that aku may mature in 1 year.

SEX RATIOS

The sex ratios obtained while sampling ovaries are of interest in that a significant departure from an expected 1:1 ratio occurs in the fall months.

The number of male and female fish obtained during the course of this sampling, together with the probability that the observed sex ratio was 1:1 as indicated by chi-square, is given in Table 3 for spring, summer, and fall.

The significant change in the sex ratio which occurs during the period from September through December corresponds to the nonspawning period (see Fig. 3) and may indicate a differential availability between male and female fish during this period. This

TABLE 3
COMPARISON OF SEX RATIOS OF AKU FOR SPRING, SUMMER, AND FALL, 1949 AND 1950

	1949			1950		
	MARCH TO MAY	JUNE TO AUGUST	SEPT. TO DEC.	MARCH TO MAY	JUNE TO AUGUST	SEPT. TO DEC.
Males	237	691	351	42	275	418
Females	205	722	214	40	240	316
Totals	442	1,413	565	82	515	734
Probability	.13	.41	<.0001	.82	.12	<.001

TABLE 4
Comparison of Sex Ratios for Both Large and Small Fish for March–August and September–December, 1949 and 1950

	Length greater than 650 millimeters		Length less than 650 millimeters	
	March–August	Sept.–Dec.	March–August	Sept.–Dec.
Males	1,077	304	168	465
Females	1,063	208	144	322
Total	2,140	512	312	787
Probability	.76	<.0001	.17	<.0001

is likewise a period of reduced availability, and, if the reduction in catch commonly experienced during the fall and winter months arises from the departure of part of the population from the areas fished, it might be suggested that a disproportionate number of female fish are among those departing.

The possibility that the observed changes in the sex ratio might be linked with changes in the sizes of fish available to the fishery was explored, as significant changes in the average size of fish in the catch does seem to occur during the year and some error may be expected in sexing the smaller sizes.

The fish sampled were placed in two groups by size—those larger than 65 centimeters and those smaller than 65 centimeters; however, the same pattern of sex ratios was displayed by both groups. (See Table 4.) If the length frequency curves (Fig. 1) are examined, it will be seen that fish of 65 centimeters are not abundant in the catch. This particular length, therefore, seems to be a natural point of division between large and small fish, at least for the dominant summer fishery.

SUMMARY

The length frequency measurements of Hawaiian aku (*Katsuwonus pelamis*) for the period from the summer of 1946 to that of 1951 contained definite modal groups which, when properly associated from summer to summer, indicated the probability of the existence of two and sometimes three year-classes in the landings which were possibly 1, 2, and 3 years of age, respectively (fish referred to as 1 year old have probably reached or are about to reach the end of their first year and are, therefore, beginning their second year of life), with modal lengths of 42 to 45 centimeters, 68 to 73 centimeters, and 79 to 80 centimeters for each of the ages given above.

A study of the schooling pattern of the aku indicated a strong tendency to school by size; no fish within a school, in the samples studied, differed by more than 20 centimeters, whereas fish present in the whole population sampled differed by as much as 50 centimeters. The possibility that the mechanism of this size segregation might depend upon the existence of a higher swimming speed for the same proportionate effort for larger fish was suggested. An alternate hypothesis, that the schools were relatively stable aggregates, seemed less likely as the variances for these pure school samples were found to be significantly nonhomogeneous.

The measurement of ova indicated that the spawning period probably extended from late February, March, or April to the first part of September, and the existence of several modes in the frequency distribution of ova diameters within individual ovaries indicated the likelihood of multiple spawnings. Fully ripe and spawned-out fish were both quite rare in the commercial catch during the spawning season, and, although these observations would indicate that fully ripe fish were not available

to the fishery, they would also imply a pattern of multiple spawning. The data did not allow an estimation to be made of the number of times aku may spawn each season.

It would appear probable, in consideration of the minimum size at maturity together with the growth rate as estimated from the length frequency curves, that aku require a year in which to reach maturity.

The significant reduction in the proportion of female fish in the landings during the fall and early winter months, coupled with the reduced catches experienced during this period, may indicate that the female fish become less available to the fishermen at this time than the males. This differential availability of females would seem to occur coincident with the end of the spawning period. This change was found not to be associated with shifts in the sizes of fish landed.

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NOTES

Report on a Fatal Attack by a Shark

Attacks by sharks on human beings in coastal waters of the United States are rare, and until comparatively recently all known cases were reported from the Atlantic Coast. However, on October 10, 1950, a swimmer at Imperial Beach, California, was attacked and seriously injured by a shark. Although this story was widely printed in the newspapers, no record of it seems to have appeared in any scientific journal. A similar attack, this one fatal, has now occurred in central California. In view of the rarity of such events and the considerable amount of evidence available in the most recent case, it seems proper to report on this latest tragic occurrence at Pacific Grove.

On December 7, 1952, at about two o'clock in the afternoon, Barry Wilson, age 17, of Pacific Grove, was attacked by a large shark while swimming close to shore. His screams, and those of an observer on shore, attracted the attention of his friend, 15-year-old Brookner Brady, Jr., of the Presidio of Monterey, who was swimming close by. Brady immediately swam to the aid of his friend and began to tow the wounded youth toward the beach. Four other swimmers, all members of the Sea Otter Club, a skin-diving group, and all excellent swimmers, were also attracted by the screams and unhesitatingly came to help Brady. These men (Sgt. Earl Stanley, 63rd Military Police Platoon, Fort Ord; Robert Shaw, 313th Criminal Investigation Detachment, Fort Ord; Frank M. Ambrosio, California State Highway Patrol, Monterey; and John L. Poskus, mathematics and physics teacher at the Monterey High School), using an inflated rubber tube to support the unconscious Wilson, brought the stricken youth to shore, where it was learned that death had already occurred.

An unusual circumstance is that John C. Bassford, assistant manager of the Monterey office of the Metropolitan Life Insurance Company, an intelligent observer and himself an enthusiastic skin-diver qualified by experience to judge what was happening in the water, saw the initial attack from an elevated vantage point at a distance of only about 30 yards. Furthermore, three of the participants in the attempted rescue have had extensive police experience and, consequently, training in the accurate observation and reporting of events of violence. In spite of the frantic excitement of the drama in which they participated, the stories of all the witnesses corroborate one another except in minor and unimportant details. As a result it is possible to make what I believe to be an accurate identification of the shark and to cast a little light on its behavior.

The attack took place just outside the breaker line, about 25 yards off the tip of Point Aulone (locally known as Lover's Point), approximately 36°38′ North Latitude, 121°55′ West Longitude. The rocky shore at the tip of the point falls off abruptly, and the water at the scene of the tragedy is about 30 feet deep. The temperature of the water was just average for that date and had been slowly falling from 14.1°C. during the previous week; 12.9°C. had been recorded at 9:00 A.M. at the Hopkins Marine Station, about three quarters of a mile to the southeast, and a reading of 12.7°C. was obtained at 6:10 P.M. on the bathing beach at the base of Point Aulone. A rather heavy surf was running to heights of perhaps 8 feet, and the water was rather murky, due to rain runoff from land on the previous night and to a comparatively heavy plankton production, so that the visibility for the men in the water was limited to a distance of 6 or 8 feet. It was an afternoon of intermittent sunshine and cloud shadow.

Mr. Bassford had just moved to an elevated vantage point on the extreme tip of the rocks in order to watch the two boys swimming almost directly below him, when he saw Wilson jerk himself around in the water and peer in all directions. In a moment he noted a look of terror on Wilson's face and then, for the first time, saw the shark approaching the youth on the surface. It struck the boy from in front and heaved him out of the water to the level of his thighs. The shark was probably turning somewhat on its side to strike at the upright figure, since Bassford had the impression of seeing the pectoral fin as well as the dorsal. Wilson, with both hands on the shark's back and pushing at arm's length in an effort to free himself, fell sideward and was immediately pulled under. Bassford feels that the boy was not submerged by the force of his own fall but was inexorably pulled down by the shark. For a moment noth-

ing was to be seen, but soon a gush of blood welled up from below and spread on the surface in a rough circle 6 feet or more in diameter. Within a matter of seconds Wilson reappeared in the center of the bloody patch, screamed for help, and struck frantically at the water with his hands. The shark reappeared at the surface, swam by very close to the youth, showing portions of its back, and then returned from the opposite direction, finally disappearing from the view of people on shore. It is uncertain that the shark actually struck at Wilson on these two passes, but apparently it did return to the attack some minutes later.

Bassford in the meantime had shouted to Brady, who was swimming slightly inshore and some 50 feet away from Wilson, in order to warn him of the danger. Brady, ignoring his own safety, swam at once to the aid of his friend and towed him some 75 or 80 feet before being met by the four members of the Sea Otter Club, who had in the meantime been summoned from a distance of 150 to 200 yards by the shouting. These men, with considerable difficulty, succeeded in passing a rubber tube around the body and under the arms of the inert victim. While they were attempting to do this, the body gave a lunge, furthering their effort. Shaw had such a strong impression that someone had pushed Wilson from behind that he turned around to see who had done it. Seeing no one, he looked quickly down into the water just in time to see see the posterior part of the shark disappearing.

With Poskus pulling on an attached nylon rope, Ambrosio and Shaw pushing on either side of the tube, and Stanley supporting Wilson's head in order to keep it out of the water, the men began a struggle through several hundred yards of churning seas to a point in the shelter of a small breakwater pier where a landing was possible. No exact estimate of the time required for that arduous journey is possible, but it must have taken more than 20 minutes. During at least some and probably most of that time the shark patrolled the swimmers but did not strike. At one time Ambrosio became aware of its presence before seeing it, probably sensing the swirls of water caused by its passage. Whenever the swimmers had to stop to rearrange the body which kept slipping from the tube as the group was battered by the breaking waves, the shark was apt to appear. Stanley, Shaw, and Ambrosio all saw it more than once. It is probable that it circled them most of the way to shore, approaching closely whenever it was necessary to halt and being kept at a slightly greater distance by the agitation of group swimming. It is possible, however, that the approaches and retreats were an illusion resulting from a better opportunity for some of the men to watch for the shark during the halts. The actions of the shark during this period were somewhat similar to those of a man-eater which, after an attack on a boy in Buzzard's Bay, Massachusetts, in 1916, stood off and on in the blood-reddened water only a few yards away during the rescue attempt but made no further attack (Gudger, E. W., Amer. Midland Nat. 44(3): 714–719, figs. 1, 2, 1951). They are also reminiscent of the behavior of a hammerhead which, after attacking a girl at Palm Beach, Florida, in 1931, followed his victim and her rescuer close in to the shore but appeared to be kept from making repeated attacks by vigorous threshing (Gudger, E. W., Nat. Hist. 40(1): 417–418, 1937).

It should be mentioned that the movements of the shark were at all times deliberate and leisurely. Neither during the initial attack, nor while making subsequent strikes, nor while convoying the swimmers toward shore, did its speed impress any observer. It made no abrupt lunges and never appeared to be exerting itself.

Wilson was examined by Dr. R. L. Hane a few minutes after having been brought to the pier and was pronounced dead as the result of his extremely severe wounds. While I am reluctant to publish the accompanying photographs of these wounds, I deem it desirable to do so and to describe their general character in order that a graphic record may be readily available for comparison in future instances when swimmers may be attacked by some unknown marine animal. Mr. and Mrs. Clarence Wilson, the parents of the deceased youth, have given me permission to do so.

The body above the hips and the lower right leg were without blemish. The major wound involved the excision of the lower part of the right buttock and practically all the muscles on the dorsal side of the thigh, almost to the knee. Although no bones were broken, the lower part of the ischium was laid bare, and the femur was exposed for about three quarters of its length. The femoral artery was severed, and shock and loss of blood from this wound alone would have caused death in a very few minutes. This wound also involved most of the lateral and medial surfaces of the thigh, so that only a narrow strip of skin about 3 or 4 inches wide on the front of the leg was undamaged. The lateral margin of the wound was ragged and characterized by ribbon-like pendants of flesh,

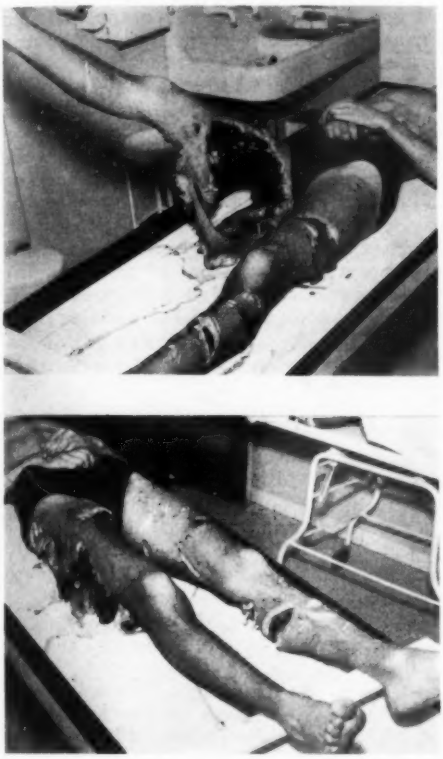


FIG. 1. Fatal wounds inflicted by a shark thought to have been *Carcharodon carcharias* (Linnaeus).

but the medial border was sharp as if cut by a knife, and the line of incision was continued by a series of equally spaced triangular cuts. An extensive festoon of skin and subcutaneous tissue connected the anterior and posterior limits of the wound dorsally. This makes it impossible to believe that the wound was inflicted by a single strike but suggests the probability that two attacks, one primarily from the medial surface and the other from a dorsolateral direction, impinged upon each other. It is significant that Stanley and Shaw, who were the first to reach Brady struggling with his burden, both saw the wound in the water and were of the impression that it was not as severe as it appeared on landing. This lends credence to the belief that the shark struck Wilson later while he was being placed in the tube and was almost surrounded by swimmers.

Additional wounds marred almost the entire left leg. The anterior and lateral surfaces of the thigh bore a wide and ugly transverse cut which extended to the bone. Similar but somewhat smaller gashes cut across the calf and shin. Some of the more superficial markings appear to me to provide better evidence of the nature of the attacker than do these more conspicuous wounds. They were of three general types. Several linear lacerations, up to about 4 inches long and probably not more than ½ inch deep, looked like razor slashes and could be interpreted as caused by shark's teeth slitting sidewise through the flesh. A number of comparatively superficial gashes, several inches long and about an inch wide and pointed at one end, could have been made by shark's teeth which were not biting deeply and were slipping through the skin longitudinally. Most significant were a few inconspicuous wounds on the left leg, each in the form of two superficial cuts meeting at an angle like the legs of an almost equilateral triangle a little over 1 inch on a side. These appeared to me to be the imprint made by the teeth of a shark which was gently mouthing instead of biting its victim. Unfortunately, they do not show on the photographs. No clear imprint of the jaws was visible, but the area of laceration on the left thigh was rather sharply defined and about 10 inches wide.

The number and character of the wounds suggest that Wilson was bitten at least four times, and the corroboratory evidence of the witnesses indicates the sequence: first, on the lower left leg from behind, which strike wounded and startled him; second, on the medial surface of the right thigh, when the shark approached him from in front and, passing partially between his legs, lifted him high out of the water; third, on the upper left leg from the back and side, when Wilson struck in desperation at the water; and, finally, on the back and side of the right thigh, while he was being placed in the tube and when he was undoubtedly already dead.

At first there was some question on the part of the police, the coroner, and the general public as to the sort of animal responsible for the attack. Barracuda, sea lions, killer whales, and even porpoises were suspected. However, all the people who witnessed the actual attack or saw the animal while participating in the attempted rescue state unequivocally that it was a shark. Three professional ichthyologists, J. B. Phillips of the California Department of Fish and Game, Robert W. Morris of the U. S. Fish and Wildlife Service, and myself, viewed the body. Although

without previous experience in such matters, it is our unanimous opinion that certain of the wounds, particularly the sharp thin slashes and the triangular cuts, could not have been made by the teeth of a sea lion, whale, or porpoise, but that they are definitely of the type that might be expected to be produced by the dentition of a shark. It should be mentioned that the California barracuda is extremely rare in the area and is of comparatively small size, reaching a length of only about 4 feet and a weight of 10 to 12 pounds. It is inconceivable that this fish could have been responsible for the major wound of the right leg. Later, Dr. Paul E. Messier also viewed the body and pronounced the wounds to be identical in character with those which he had observed some years ago in two cases of shark attack in the tropical Pacific.

In a forlorn attempt to capture and definitely identify the shark, the research vessel "Tage" fished for it next day in the adjacent area while several people tried their luck from shore. Although these efforts were unsuccessful, a considerable amount of evidence supports a tentative specific determination. Shaw had a good although brief view of the shark's tail and described it as tuna-like, with a spread of about 3 feet and with the upper lobe a little longer than the lower one. The accuracy of his observation is indicated by the fact that he also noted a small flap-like structure on the back in front of the tail but stated that this was not the dorsal fin. At the time I questioned him, he did not know that the shark had the small second dorsal of which he gave such an adequate characterization. Shaw's description, supported by that of others, fits the caudal fin of the families Lamnidae and Cetorhinidae but of no others. The sluggish, plankton-feeding *Cetorhinus maximus*, which has never been suspected of such aggression, is at once ruled out as a possible offender. The color, unanimously stated to be light and variously described as grayish or brownish merging into white underneath, does not fit either *Lamna ditropis* or *Isurus glaucus*, the only other members of the Lamnidae known from these waters, but points the finger of guilt directly at *Carcharodon carcharias*. The suspicion is further strengthened by the broad apex of the triangular wounds. These marks matched closely the shape of the teeth of *Carcharodon*, but I do not believe they could possibly have been made by the much narrower teeth of *Lamna* or *Isurus*. The most common large shark seen in the area is *Prionace glauca*. By a stretch of the imagination the wounds, although they showed no concavity of one border, might possibly be interpreted as having been inflicted by the teeth of this species. However, the striking blue color of the dorsum and the great disparity in the length of the caudal lobes of *Prionace* vary widely from all the reported observations. Finally, when it is recalled that *Carcharodon* is so notorious for unprovoked attacks on humans that it has gained the common name of man-eater and that, although uncommon along the California coast, specimens of this species have previously been taken in Monterey Bay and even as far north along the coast as Westport, Washington (Bonham, K., Copeia 4: 264–266, figs. 1–7, 1942), there is comparatively little doubt that this shark was responsible for the attack. All the evidence available tends to incriminate *Carcharodon* and to absolve the other possible suspects.

Estimates of the size of the shark vary from about 8 feet to 15 feet, or even more. The size of the toothmarks, the width of the gape as indicated by the dimensions of the lacerated area of the left thigh, the estimated spread of the tail, all indicate a length of approximately 12 or 13 feet, but this estimate may be more than 10 per cent in error.

I find it impossible to close this report without recalling to the reader's attention what must already be abundantly clear: the outstanding courage of the five young men who made the rescue attempt. How Brady could have deliberately gone into the circle of bloody water to succor his friend and how the other men could have persisted in the slow and laborious task of supporting and carrying their lugubrious burden for more than a quarter of an hour while a known deadly killer circled within a few feet of them surpasses all understanding.—*Rolf L. Bolin, Hopkins Marine Station, Pacific Grove, California.*

News Notes

The International Code of Nomenclature for Cultivated Plants has recently been published under the editorship of William T. Stearn. This is a joint product of the International Horticultural Congress and the International Botanical Congress. Copies can be obtained for 1s./3d. from the Royal Horticultural Society, Vincent Square, London S.W. 1, England.

With the October 1953 number of Pacific Science, W. A. Gosline assumed the duties of Associate Editor, replacing O. A. Bushnell, who is on leave for advanced study at Columbia University.

PETTIBONE, MARIAN H. *Some Scale-Bearing Polychaetes of Puget Sound and Adjacent Waters.* 89 pp. + 40 pls. University of Washington Press, Seattle. $3.25.

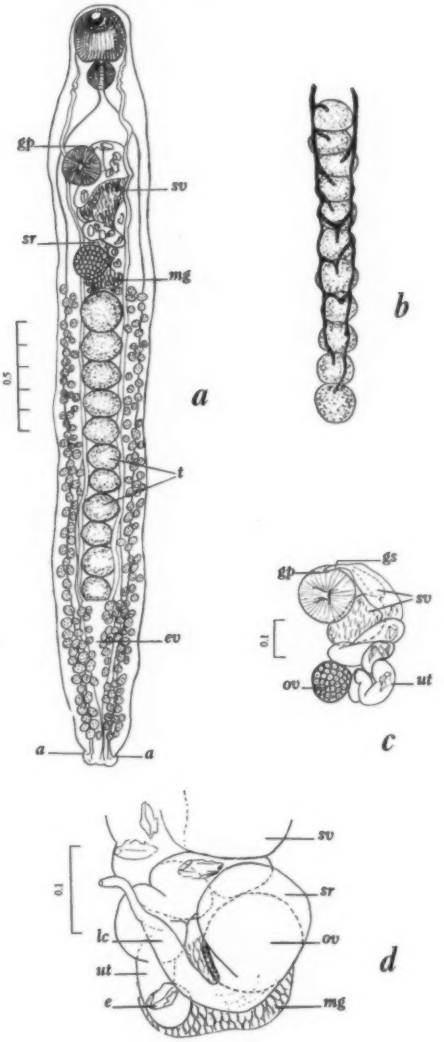
PAUL H. BALDWIN. *Annual Cycle, Environment and Evolution in the Hawaiian Honeycreepers (Aves: Drepaniidae).* University of California Publications in Zoology 52(4): 285–398, 12 figs., 4 pls. Published by the University of California Press. $1.50.

We have received the first number of a new quarterly journal, *Deep-Sea Research*, which is published by the Pergamon Press, London. It has been established under the instigation of the Joint Commission on Oceanography, of the International Council on Scientific Unions. The journal is limited to papers on investigations of the deep-sea floor, specifically:

1. The morphology and stratigraphy of the deep-sea floor.
2. The general properties of the sediment carpet and its substratum.
3. The properties of the water layer next the deep-sea floor.
4. The abyssal fauna inhabiting the deep-sea floor.
5. The organisms and processes important to deep-sea sediments.

The editorial board, which is truly international, is composed of outstanding workers in oceanography and assures the highest standards, which are well set by the initial number.

Deep-Sea Research. Pergamon Press Ltd. Distributed by Lange, Maxwell and Springer, Ltd., 242 Marylebone Road, London N.W.1. Subscriptions £4 10s, or $12.60.

Erratum

In the October 1953 issue (Vol. VII, No. 4) there is a serious error. On page 508, Figure 4*d* is transposed from Figure 1 on page 449. Figure 1 of the paper, "A Discussion of the Trematode Genus *Schistorchis* (Family Lepocreadiidae) with Descriptions of Two New Species from Hawaii," by Mary Louise Hanson, is printed correctly below.